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Scientific, Technical and Economic Committee for Fisheries (STECF)

Report of the SGMOS-07-01 Working group on the Evaluation of "Policy statement harvest rules”

12 – 16 MARCH 2007, LISBON

Edited by Alan Sinclair, Hendrik Dörner & Franz Hölker

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SCIENTIFIC, TECHNICAL AND ECONOMIC COMMITTEE FOR FISHERIES (STECF)

STECF COMMENTS ON THE REPORT OF THE WORKING GROUP ON MANAGEMENT OF STOCKS (SGMOS)

12 – 16 MARCH 2007, LISBON

EVALUATION OF "POLICY STATEMENT HARVEST RULES" (SGMOS 07-01)

STECF OPINION EXPRESSED DURING THE PLENARY MEETING

OF 23-27 APRIL 2007 IN ISPRA

Background and terms of reference to the STECF

The Communication COM (2006) 499 final (Fishing Opportunities for 2007. Policy Statement from the European Commission) sets out the rules that the Commission intended to apply in 2006 in order to make TAC proposals for 2007, based on stock assessments and forecasts provided by ICES and STECF. The rules were established on a policy basis, with a high priority on providing stability for the industry where possible, although the likely long-term consequences of applying such an approach had not been evaluated. The Commission intends to pursue a similar approach for 2008 by preparing a Communication in April 2007 establishing the intended TAC-setting rules. However, the Commission wishes to obtain scientific advice concerning the likely effects of applying such rules, even if this exercise is preliminary in nature. The request for advice covers only those stocks not already subject to long-term plans (for which specific requests for advice have already been made) and also excludes stocks where no analytic assessment is available (as that topic is intractable at present).

STECF should deliver an opinion based on the work of the subgroup SGMOS-07-01 (12-16 March).

In the following, TAC-setting rules are referred to a TAC decision rules (TDR).

Terms of reference for the SGMOS-07-01 (12-16 March, 2007) Expert group

The terms of reference of the Subgroup were as follows:

Examine the TAC-setting rules in paragraphs 4.1, 4.2 and 4.3 of the Commission's Communication COM (2006) 499 final (Fishing Opportunities for 2007. Policy Statement from the European Commission), and to advise on the likely long-term (ca. 10-year) consequences, and associated risks for the stocks and the fisheries, in terms of:

a) The future development of spawning biomass, and associated risks of transgressing biological reference points.

b) The future development of yield, and associated risks. STECF may provide recommendations concerning the relevant harvest rules in order to improve stability, diminish biological risks, or to increase yields.

STECF is also requested to evaluate the consequences of applying the TAC-setting rule in paragraph 4.6 so far as possible (including planning further work, if necessary). However, the terms of reference for the working group exclude this question (see last paragraph of previous section).

Technical background from the Commission services to the Subgroup

In addition, the Commission provided the following guidance.

The comments in this section are intended to assist STECF in its deliberations, but are not intended to be constraining.

The request should be addressed using stochastic simulations of fish stock dynamics simulating stock measurement and assessment procedures and implementation methods (Operating model/ Management procedure approach). Given the large number of fish stocks it is probably not realistic to simulate procedures for each stock individually. Instead, a smaller number of calculations based entirely on simulated data could be used to characterise the risks and benefits of applying the harvest rules in various circumstances. As a baseline, these could include:

Simulated population:

a) Stock- recruit relationship with either a shallow or a steep slope at the origin.
b) Growth and maturation: Examples based on an early-maturing fish (e.g. herring) and a later-maturing fish (e.g. cod) should be used.
c) Starting conditions: Four examples should be simulated:
    i. "well managed" : F close to Fmsy and B close to Bmsy
    ii. "overfished" : F three times Fmsy and B close to Bmsy
    iii. "depleted" : F close to Fmsy and B one-third of Bmsy
    iv. "depleted and overfished" : F three times Fmsy and B one-third Bmsy.

Notes :

a) Fmsy and Bmsy are suggested instead of Fpa and Bpa because the former values can be calculated in a case-independent fashion.
b) F0.1 could be used as a proxy for Fmsy here)
c) The "three times – F / one-third in Biomass rule has a non-empirical basis.

Implementation Rules:

An assumption of a bias in either or both assessment and in implementation at a realistic recent level should be calculated as a robustness test. Overall this schema would provide a minimum of 4x2x2x2 = 32 simulation scenarios.

The following results should be presented for each scenario: appropriate percentiles (e.g. 5th, 25th, 50th, 75th and 95th.) of fishing mortality relative to Fmsy and to F0.1, biomass relative to Bmsy, yield relative to yield in the starting conditions, and recruitment levels. STECF is however encouraged to provide a wide-ranging exploration of the issue and to report in appropriate detail.

The advice is requested for 31st March 2007 at the latest, in order to allow for the conclusions to be considered by the Commission when preparing the Policy Statement for the 2008-fishing year.

Sub-group results: summary

The SGMOS made considerable progress during the meeting in formulating an approach to address the terms of reference. However, it was not possible to complete the evaluation in the time available due to the technical and conceptual difficulties of the task.

The meeting participants were able to describe the three TDRs in sufficient detail to generate the required computer simulation code. This task required considerable discussion and debate to ensure a common understanding of terminology and intent. Participants also agreed that the three rules could be combined, and with an annual evaluation of population status, the combined rule could be applied for longer-term simulations that covered a spectrum of stock conditions. Simulated fisheries datasets were created that reflected the initial conditions of exploitation and depletion for which the three TDRs were designed. The agreed approach was to select three species 'types' with differing life histories to provide contrast in the simulation testing of the combined rule. In addition, it was decided to use two different stock/recruitment formulations for each species reflecting different levels of recruitment compensation. The model was coded in three different software environments (FLR, AD model builder and Visual Basic) to begin evaluation of the TDRs. Having at least three applications was in principle considered an advantage since it provides a basis for checking algorithm coding. However, owing to shortfalls in model implementations it was not possible to fully address the TOR

The sub-group was not able to include economic evaluations in these simulations. This means, for example, that two management options resulting in the same biological risk but with different economic performance, would be indistinguishable to decision makers and stakeholders.

Additional work is required to fully address the meeting terms of reference. Guidance on the further work required is provided below. A follow-up meeting could be held in September 2007, to complete the evaluation and it is essential to maintain the interest generated by this meeting during an intersessional period in order that adequate preparatory work is completed.

STECF comments on the Report of the SGMOS (07-01) subgroup.

It is clear that the SGMOS (07-01) did not achieve its objectives. In view of the initial progress and investment of resources, and given that there is there is a strategic need for software and skills capable of testing alternative management strategies for future requests made to STECF, there is a good case for a follow up meeting, and STECF is supportive of this.

The single most important and also likely most demanding, task is to correctly model the level of knowledge (correct simulation of uncertainties) in fisheries. In the assessment model, the most appropriate information to include is that estimated from the simulated data sets. For example, parameter values (like M) should not automatically be assumed to be the same in operational model (simulated truth) and in the assessment model, as these are not known in reality either. STECF feels that more work is needed here to get a similar understanding among scientists

In the longer term, there is a need to increase the ease with which results can be understood, not least because stakeholders have an interest in the implications of the results and need to understand them. The conceptual difficulties of using operational models and assessment models at the same time in computer simulations, as well as providing simulation results in probabilistic terms, may create problems for some stakeholders to interpret results as effectively as may be hoped. A lack of clarity and reduced comprehension is not likely to assist ‘buy-in’ and support for management proposals, which is currently important e.g. in RAC activities. Communication of the concept is not a concern within the WG. However, it can pose a challenge when communicating with a wider audience.

STECF also considers that even more standardization in the use of terms and phrase would be helpful. For example, the word “estimate” has been used both for the values of operational models, and also for the values estimated by the assessment model inside of the simulation loops. More specific wording may be required to avoid misunderstandings. There is clearly a need to use logical words from the outset, and it would also improve the communication in the future meetings. The sub-group report included a list of terminology, but this does not totally cover all aspects of the required terminology.

Age	s	M	W (kg)	m
1	0.4	0.8	0.355	0.01
2	1	0.35	0.819	0.05
3	0.98	0.25	2.09	0.23
4	0.86	0.2	3.976	0.62
5	0.78	0.2	6.203	0.86
6	0.77	0.2	8.309	1
7	0.77	0.2	9.963	1
8	0.76	0.2	11.114	1
9	0.8	0.2	12.454	1
10	0.87	0.2	13.493	1
11	1	0.2	14.07	1
12	0.76	0.2	15.212	1
13	0.76	0.2	17.051	1
14	0.76	0.2	17.986	1
15	0.76	0.2	17.333	1

Even though the work was carried out for only a limited number of stock types('codoid', 'hakeoid' and 'heroid' and the F_{pa} was assumed to be half of F_{msy}, the differences between the reference point yields and biomasses (Table 3-1) is an interesting example of what kind of catch losses may arise if alternative reference points to F_{msy} are followed. It may be valuable if ICES could estimate the benefit gained by following the objective given in the Johannesburg agreement (to reach B_{msy} by year 2015) for as wide a range of stocks as possible and include that in its advice to get an estimate of potential gains. It is well understood by STECF that this is an uncertain estimate among all other uncertain estimates provided in fisheries science and very dependent on the S/R model and S/R data applied. Correct ways to estimate the uncertainties (probability distributions) of reference points and corresponding yield and biomass are required here.

STECF response to questions raised by the SGMOS (07-01) Subgroup

In the following, STECF comments on some of the outstanding questions posed by SGMOS (where STECF had expertise).

1) How best to ensure accurate and bug-free coding? It may be sensible to generate a known test data set that will be useable across programming environments, and be used for cross-validation.

It is obvious that, due to the complexity of the modelling, there is a high need to ensure the quality of the software. This should be carried out at least by test data sets and by comparing different model packages. In addition, continuation of international co-operation with experts from outside EU could be helpful and may also help to investigate the sensitivity of the results to the different technical solutions to the simulation process.

During the meeting it was not decided to what extent variability in biological parameters such as weight at age, selectivity at age, maturity, etc. should be included in the simulations. This needs to be determined and stated explicitly.

2) It is of crucial importance to correctly describe all sources of uncertainty in the assessment. All essential variables should have associated probability distributions, which describe the likely future variability. Also the correlations between the variables should be taken into account (like mean weight and selectivity and S/R parameter estimates). Also during the meeting, no implementation uncertainty was included in the testing of the TDRs. A decision is required on whether to include this, for example, how should unreported catch and discards be considered?

STECF comment: As the TDR tests are made to get a realistic view about assessment uncertainties and management success and their interdependencies, also the implementation error (implementation of management measures) should be included. There is in several cases data available (difference between realized catch and TAC) and consultation with stakeholders may be helpful. Poor implementation implies that a bigger buffer is required against stock decline. The most likely behavior in the cases simulated (the stocks here were general cases) should be applied, and the sensitivity of management success analyzed by changing assumptions about misreporting and discards. The impact of these factors may be of interest to industry, as well.

3) There is presently an intrinsic two year time lag between data becoming available (up to year y-2) and setting the TAC (in year y). The influence of this time lag should be explored to determine its influence on the behavior of the TDRs.

STECF agrees that this is a complicated issue and should be investigated. In particular the linking of correct use of real assessment methods to these times lags is likely to be demanding.

4) The different programming environments include simulation strategies that include a formal assessment (such as XSA in the FLR routines) and others that simply simulate the stock assessment process by sampling from the true population (such as the Visual Basic implementation). These can be used to determine how important it is to include an explicit stock assessment model. This is related to whether or not the F and SSB reference points (FMSY, Fpa, and Bpa) are estimated from simulated data in an assessment or are taken as known.

Theoretically those assessment models should be used, which are also used in reality, to more correctly mimic the likely future success of management scheme. This needs to be thoroughly tested.

5) Finally, the stock-recruitment functional forms need biological reality. If a Ricker is used, the unfished equilibrium SSB should be relatively close to the biomass giving maximum recruitment. In the codoid example, the unfished equilibrium was more than three times the biomass giving maximum recruitment and this caused huge oscillations in behaviour, something never seen and unexpected. Introducing process error into the stock-recruitment function is also a problem. Lognormal errors is assumed but this could be added as a Monte Carlo process, in which case autocorrelation could also be added. Alternatively, observed residuals could be resampled, although with only short time series of data this may not be sufficiently variable.

STECF comment: It is obvious that the use and choice of S/R model is one of the key assumptions of the simulation tests. There is a need to test the effects of using several potential models, as well as different ways to create randomness to the results. The sampling system applied in simulations (including correct correlation between parameters) must correctly transfer the uncertainty of historical data to the future simulations. Sampling from a Bayesian posterior would be conceptually easy way and it would offer a way to include additional information in the format of priors (like e.g. using the Bothnian Sea S/R data for the Baltic Main Basin herring stock analysis). Due to the fact that S/R relationship is usually the most uncertain part of any stock assessment or management evaluation, this issue needs much more work to be done in EU fisheries.

STECF Conclusions

STECF concludes that the subgroup was unable to fully address the TOR in the time available. This seems to have been partly because the appropriate tools were not available before the meeting.

STECF also concludes that good progress was made in describing and coding the TDRs and suggests that the complexity of this task is often underestimated.

STECF underlines the need to include economic impact evaluations to the analyses. CFP legislation requires this, and economic information may help the stakeholders to find acceptable management options more easily. STECF aggress with SGMOS that a follow up meeting would be valuable but stresses that additional progress and the completion of the TORs is only likely to be achieved if adequate intersessional work is undertaken.

SGMOS 07-01 WORKING GROUP REPORT

EVALUATION OF "POLICY STATEMENT HARVEST RULES" (SGMOS 07-01)

Lisbon, 12-16 March 2007

This report does not necessarily reflect the view of the European Commission and in no way anticipates the Commission's future policy in this area

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1. EXECUTIVE SUMMARY

This meeting was convened to formulate scientific advice on the likely outcome of applying TAC Decision Rules (TDR) adopted in 2006. While considerable progress was made during the meeting in formulating an approach to address the terms of reference, it was not possible to complete the evaluation.

Meeting participants were able to describe the three TDRs in sufficient detail to generate the required computer simulation code. This task, while seemingly trivial, required considerable discussion and debate to ensure a common understanding of terminology and intent. Participants also agreed that the three rules could be combined, and with an annual evaluation of population status, the combined rule could be applied for longer term simulations that covered a spectrum of stock conditions. Simulated fisheries datasets were created that reflected the initial conditions of exploitation and depletion for which the three TDRs were designed. The agreed approach was to select three species with differing life histories to provide contrast in the simulation testing of the combined rule. In addition, it was decided to use two different stock/recruitment formulations for each species reflecting different levels of recruitment compensation. Computer code was written to begin evaluation of the TDRs in three different environments. Having at least three applications was considered an advantage since it provides a basis for comparative algorithm testing. However, it was not possible to fully test each application during the meeting, and while some results were obtained, these were considered insufficient.

Additional work is required to fully address the meeting terms of reference. Direction of what work is required is provided in this document. It will be important to maintain the interest generated by this meeting during an intersessional period. A follow-up meeting could be held in September, 2007, to complete the evaluation.

2. INTRODUCTION

2.1. Background: of "Policy Statement" rules

The Communication sets out the rules that the Commission intended to apply in 2006 in order to make TAC proposals for 2007, based on stock assessments and forecasts provided by ICES and STECF. The rules were established on a policy basis, with a high priority on providing stability for the industry where possible, although the likely long-term consequences of applying such an approach had not been evaluated.

The Commission intends to pursue a similar approach for 2008 by preparing a Communication in April 2007 establishing the intended TAC-setting rules. However, the Commission wishes to obtain scientific advice concerning the likely effects of applying such rules, even if this exercise is preliminary in nature.

The request for advice covers only those stocks not already subject to long-term plans (for which specific requests for advice have already been made) and also excludes stocks where no analytic assessment is available (as that topic is intractable at present). For example, a zero TAC has been established for the Bay of Biscay anchovy in 2007. This catch limit may be revised by the Commission in the light of scientific information collected during the first half of 2007.

2.2. STECF is requested to (ToRs)

- examine the TAC-setting rules in paragraphs 4.1, 4.2 and 4.3 of the Commission's Communication COM(2006) 499 final (Fishing Opportunities for 2007. Policy Statement from the European Commission), and to advise on the likely long-term (ca. 10-year) consequences, and associated risks for the stocks and the fisheries, in terms of:

(a) The future development of spawning biomass, and associated risks of transgressing biological reference points.

(b) The future development of yield, and associated risks. STECF may provide recommendations concerning the relevant harvest rules in order to improve stability, diminish biological risks, or to increase yields.

STECF is also requested to evaluate the consequences of applying the TAC-setting rule in paragraph 4.6 so far as possible (including planning further work, if necessary). However, the terms of reference for the working group exclude this question (see last paragraph of previous section).

2.3. Technical background from the Commission services

<u>The comments in this section are intended to assist STECF</u> in its deliberations, but are not intended to be constraining.

The request should be addressed using stochastic simulations of fish stock dynamics simulating stock measurement and assessment procedures and implementation methods (Operating model/ Management procedure approach). Given the large number of fish stocks it is probably not realistic to simulate procedures for each stock individually. Instead, a smaller number of calculations based entirely on simulated data could be used to characterise the risks and benefits of applying the harvest rules in various circumstances. As a baseline these could include:

a) Simulated population :

Stock- recruit relationship with either a shallow or a steep slope at the origin.

Growth and maturation: Examples based on an early-maturing fish (e.g. herring) and a later-maturing fish (e.g. cod) should be used.

Starting conditions: Four examples should be simulated:

(i) "well managed" : F close to Fmsy and B close to Bmsy

(ii) "overfished" : F three times Fmsy and B close to Bmsy

(iii) "depleted" : F close to Fmsy and B one-third of Bmsy

(iv) "depleted and overfished" : F three times Fmsy and B one-third Bmsy.

Notes :

(i) Fmsy and Bmsy are suggested instead of Fpa and Bpa because the former values can

be calculated in a case-independent fashion.

(ii) F0.1 could be used as a proxy for Fmsy here)

(iii) The "three times – F / one-third in Biomass rule has a non-empirical basis.

b) Implementation Rules

An assumption of a bias in either or both assessment and in implementation at a realistic recent level should be calculated as a robustness test. Overall this schema would provide a minimum of 4x2x2x2 = 32 simulation scenarios.

The following results should be presented for each scenario: appropriate percentiles (e.g. 5th, 25th, 50th, 75th and 95th.) of fishing mortality relative to Fmsy and to F0.1, biomass relative to Bmsy, yield relative to yield in the starting conditions, and recruitment levels. STECF is however encouraged to provide a wide-ranging exploration of the issue and to report in appropriate detail.

2.4. Timescale for the provision of advice

The advice is requested for 31st March 2007 at the latest, in order to allow for the conclusions to be considered by the Commission when preparing the Policy Statement for the 2008 fishing year.

2.5. Participants

Invited experts:

Alan Sinclair (chairman; Fisheries and Oceans, Canada)

Malcolm Haddon (University of Tasmania, Australia)

Marcel Marchiels (IMARES, Ijmuiden, The Netherlands)

Manuela Azevedo (IPIMAR, Lisbon, Portugal)

Dorleta Garcia (AZTI, Sukarrieta, Spain)

Enrique de Cardenas (SGPM, Madrid, Spain)

Ernesto Jardim (IPIMAR, Lisbon, Portugal)

Steven Holmes (FRS, Aberdeen, Scotland)

Robert Scott (CEFAS, Lowestoft, United Kingdom)

Iago Mosqueira (CEFAS, Lowestoft, United Kingdom)

Morten Vinther (DIFRES, Charlottenlund, Denmark)

STECF members:

Hajo Raetz (Institute for Sea Fisheries, Hamburg, Germany)

Sakari Kuikka (University of Helsinki, Finland)

European Commission:

Hendrik Doerner (DG JRC, STECF secretary)

Franz Hoelker (DG JRC, STECF secretary)

Kenneth Patterson (DG FISHERIES AND MARITIME AFFAIRS)

3. SIMULATION METHODS

The terms of reference were addressed with computer simulations of the fisheries management procedure. The methods used are described in this section. The first section describes the TAC decision rules (TDR) in detail. The second section describes procedures for generating starting conditions for decision rule testing. The third section describes the forward simulations for applying the TAC decision rules. The fourth section describes measures used to evaluate the performance of the rules.

3.1. TAC Decision Rules

It was attempted to make TAC decision rules (TDRs) that, to the fullest extent possible, translated the rules as set out in Commission document COM (2006) 499 final directly into coded algorithms. Where guidance was not explicit, the working group used precedent from stock assessment working groups. Because simulations were based upon generic rather than specific stocks, the working group was required to make its own interpretation of a stock 'inside safe biological limits'. This was interpreted to be a stock with spawning stock biomass at or above a precautionary reference level (B_{pa}) where B_{pa} is the spawning stock biomass at equilibrium corresponding to a yield which is one half of maximum sustainable yield (MSY). A precautionary fishing mortality (F_{pa}) was then defined as the fishing mortality (taken as a mean over all ages) that gave a yield of 0.5* MSY when the population is at B_{pa}.

The following structural assumptions were used: The object of the TDR is to determine a TAC for year y. An assessment was done in year y-1 using catch and population index (CPUE, survey) data up to and including year y-2. This produced fishing mortality estimates up to and including year y-2, and SSB estimates at the beginning of year y-1. A status quo fishing mortality (F_{SQ}) was calculated as the mean fishing mortality at age over the last 3 years of the assessment (y-4 to y-2). A forward projection was then done using F_{SQ} in year y-1 to estimate the catch in y-1 and the population biomass at the beginning of year y. The variables F_{y-1} and spawning stock biomass SSB_y were used to determine which TDR to apply. The TDR was then applied to determine the TAC for year y.

3.1.1. Stocks exploited consistently with maximum sustainable yield

A stock was considered to fall into this category if mean F_{y-1} was below F_{MSY} and B_y was greater than B_{pa}. The TDR under these circumstances is described under section 4.1 of Commission document COM (2006) 499 final. It states that a TAC should be set

> to the forecast catch established by STECF as corresponding to an F_{MSY} proxy, but no more than 15% higher or lower than the TAC in 2006.

As the document refers to fishing opportunities in 2007, the TAC in 2006 is interpreted more generally as the TAC already set for year y-1. A decision diagram for this TDR is shown in Figure 3.1. The top of the figure represents the process conducted within the short term forecast used to set the TAC. SSB_{y-2} represents the SSB estimated at the beginning of the terminal year of a stock assessment. Fishing mortality applied to the stock in the terminal year and in the intermediate year (y-1) was taken to be F_{SQ}, which is the mean fishing mortality estimated for the last 3 years in the assessment (y-4 to y-2). In the TAC year (y) F_{MSY} is applied to the projected stock at the start of the TAC year according to the TDR. It is standard practise to estimate catch for a given target fishing mortality in the prediction year and then, if historical discard information is known, to split the result into a landings and discards component. TAC is then set equal to the landings component.

The rule of COM 499 section 4.1 states that the TAC for the prediction year must not differ from the TAC already set for the intermediate year by more than 15%. Once an initial TAC has been set for the prediction year it must be tested whether it conforms to this requirement. The diamond shaped symbols represent tests for the TAC being too large and too small in turn. The rectangular boxes represent actions taken if a test is failed. Once the set TAC has either passed both tests, or been adjusted to conform to the ± 15% rule, the result is the final TAC for year ‘y’.

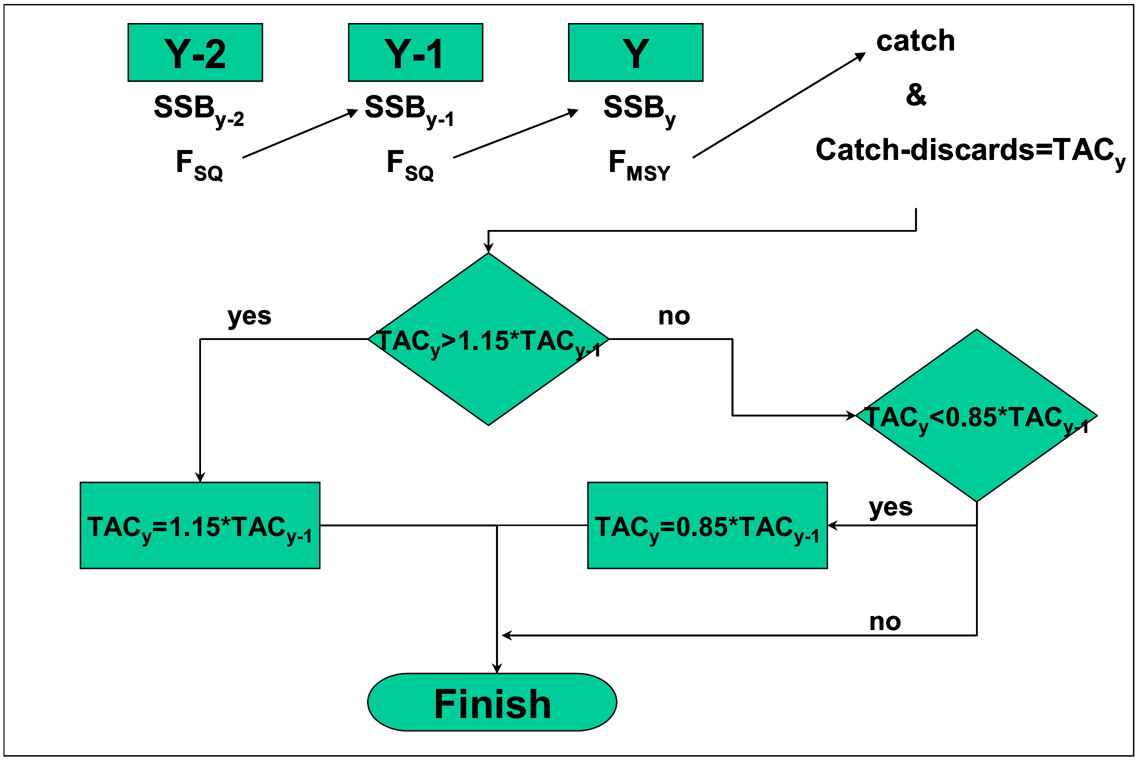

Figure 3-1 : Decision diagram relating to section 4.1 of Commission document COM(2006) 499

3.1.2. Stocks overexploited with respect to maximum sustainable yield but inside safe biological limits

A stock was considered to fall into this category if F_{y-1} falls between F_{MSY} and F_{pa} and SSB_y is greater than B_{pa}, (F_{pa} and B_{pa} defined under section 3.2). The TAC decision rule under these circumstances is described under section 4.2 of Commission document COM(2006) 499 final. It states that a TAC should be set

> to the forecast catch established by STECF as corresponding to the higher value of (a) an F_{MSY} proxy or (b) unchanged fishing mortality, but not more than 15% higher or lower than the TAC in 2006.

As the document refers to fishing opportunities in 2007, the TAC in 2006 is interpreted more generally as the TAC already set for the intermediate year. A decision diagram for this TDR is shown in Figure 3.2. The only change compared to the TDR referred to in section 3.1.1 is the choice of target fishing mortality chosen in the TAC year, (highlighted on figure 3.2 in red). Fishing mortality applied to the stock in the terminal year and in the intermediate year was taken to be F_{SQ}, which is the mean fishing mortality estimated for the terminal year. For the TAC year the higher of F_{SQ} or F_{MSY} is used to provide the forecast catch.

It is standard practise to estimate catch for a given target fishing mortality in the prediction year and then, if historical discard information is known, to split the result into a landings and discards component. TAC is then set equal to the landings component.

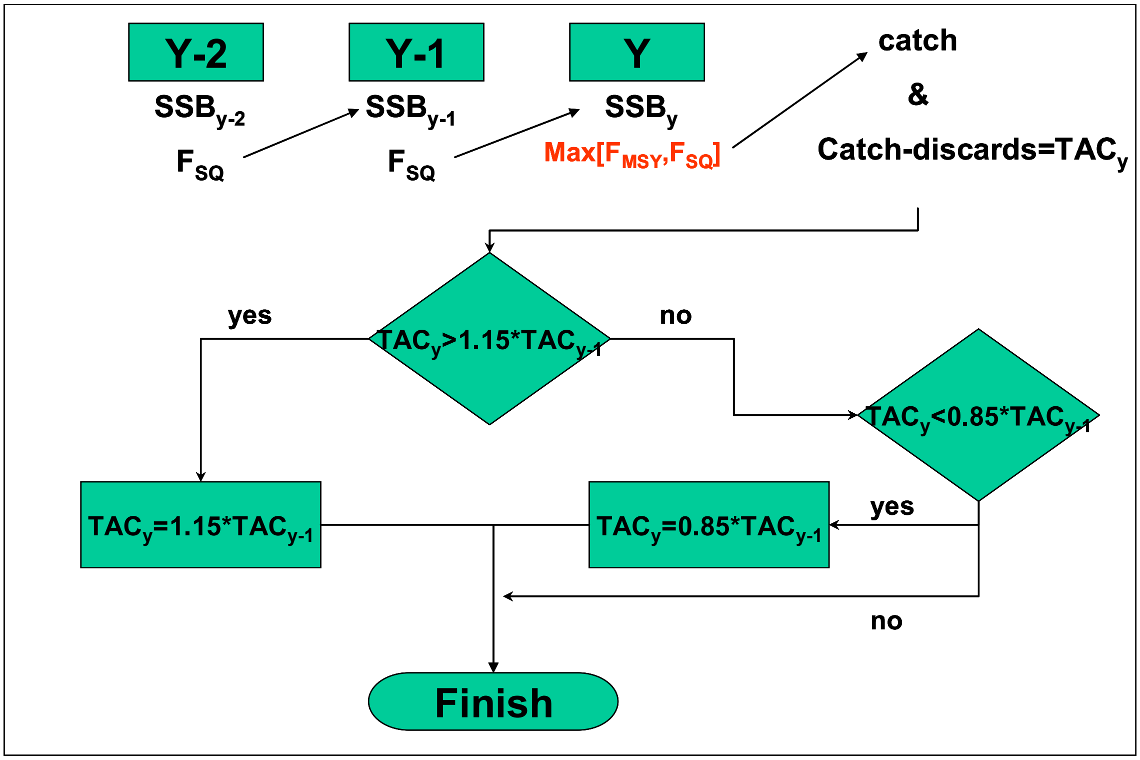

Figure 3-2 : Decision diagram relating to section 4.2 of Commission document COM(2006) 499.

3.1.3. Stocks outside safe biological limits

A stock was considered to be in this category if mean F_{y-1} is greater than F_{pa} or SSB_y is less than B_{pa}, (F_{pa} and B_{pa} defined under section 3.1). The TAC decision rule under these circumstances is described under section 4.3 of Commission document COM(2006) 499 final. It states that a TAC should be set

- as a general rule, to the forecast catch established by STECF as corresponding to bringing the stock inside safe biological limits in 2008, but no more than 15% higher or lower than the TAC in 2006,

- however, the TAC will in no case be set at a level that will lead to an increase in fishing mortality nor to a decrease in spawning biomass, even if this means a bigger reduction in the TAC than 15% (doing so would be counter to the Council and the Commission's commitments on the gradual approach to sustainability).

As the document refers to fishing opportunities in 2007, the TAC in 2006 is interpreted more generally as the TAC already set for the intermediate year. The aim of the TDR is to return the stock to within safe biological limits at the end of the year of application of the TAC being decided. A decision diagram for this TDR is shown in Figure 3.3. The term 'return to within safe biological limits' was interpreted as $SSB_{y+1} \geq B_{pa}$ and $F_y \leq F_{pa}$.

The area to the left hand side of Figure 3.3 applies the same tests and possible revisions to the TAC as seen for the TDRs in section 3.1.1 and 3.1.2. It may be possible that SSB_{y+1} can be brought equal to B_{pa} and F_y can be reduced to F_{pa} with a TAC change of less than 15%. If so, the initial TAC would be set at that level. A second test is required however, to find a TAC that does not cause a reduction in SSB or an increase in F. It is also possible that SSB_{y+1} can not be brought equal to B_{pa} or F_y cannot be reduced to F_{pa} with a TAC reduction of 15%. In this instance the TAC would be set such that both SSB does not decline and F does not increase. As such these tests for decline in SSB and increase in F must be the second set to be conducted.

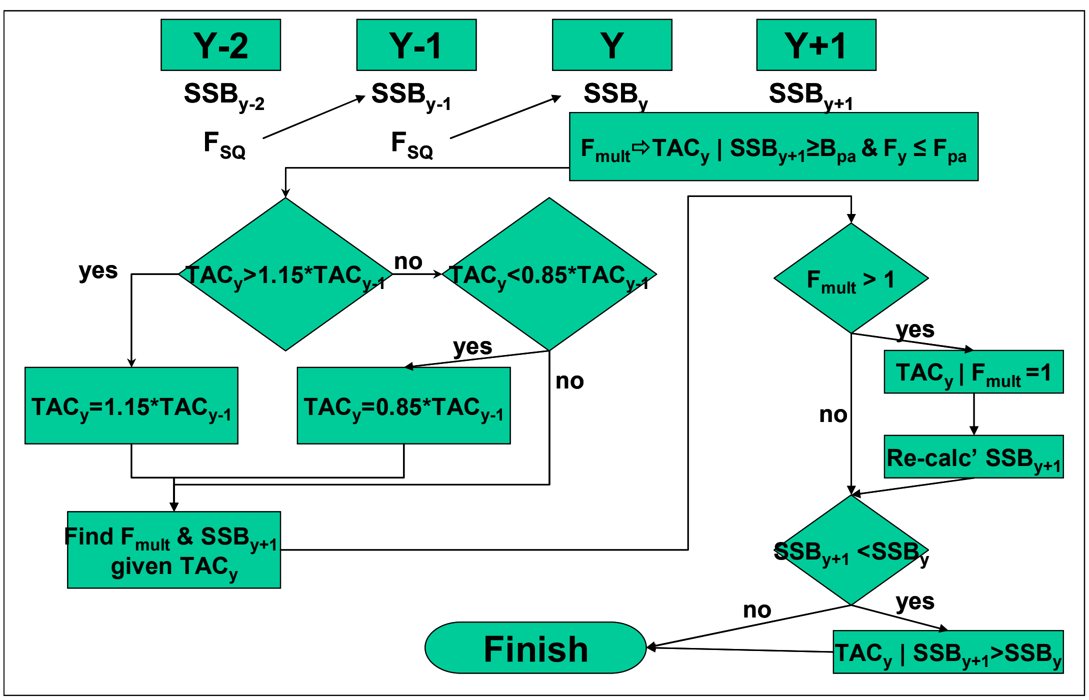

Figure 3-3 : Decision diagram relating to section 4.3 of Commission document COM(2006) 499.

3.1.4. Combined decision rule that includes evaluation of stock condition

While these three TDRs have been discussed as if they were separate units, it is possible to combine them into a single coherent whole. This whole can be used as a single larger decision rule in the management of the stock involved.

To characterize the current condition of a stock an assessment is performed to estimate the value of a number of performance measures. There are two fishery performance measures and one management performance measure that need to be considered when implementing the three TDRs as listed in the policy document; the fishery performance measures are the instantaneous fishing mortality rate and the spawning stock biomass, while the management performance measure is the potential change in the TAC required to achieve the management target.

The first performance measure to be considered in the descriptions of the different TDRs in the policy document (COM, 2006) is the estimated instantaneous fishing mortality rate. The fishing mortality performance measure can be considered as a single spectrum of values along which the different control rules are applied depending on the assessed value. In the case of fishing mortality there are two thresholds, the F_{MSY} and the F_{pa}. In all cases it is also implied that the stock must be kept above the precautionary spawning stock biomass level (B_{pa}). This is the only threshold defined for biomass. When these two performance measures are combined (Figure 3.4) it becomes clear which TDR should be applied under which sets of conditions.

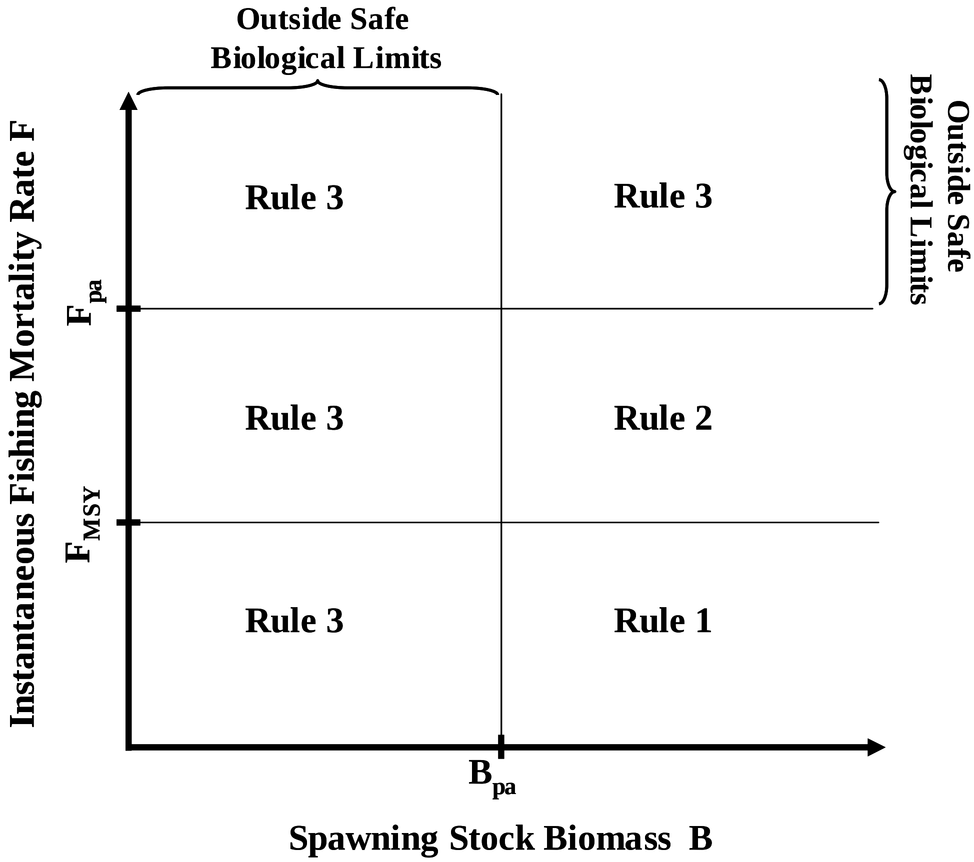

Figure 3.4 Diagrammatic representation of the ranges of estimated fishing mortality levels and the spawning stock biomass that lead to the use of the three different TAC Decision rules.

While it is possible to apply these different TDRs as if they were independent rules, their structure leads naturally to using them as a sequential series of responses depending on the variations in the status of a stock that are likely to arise from natural variation in survivorship and recruitment. The predictions of system performance given above seem logical given the structure of the TDRs. However, the objective of the simulation work is to determine if these predictions are accurate.

A formal description of the TAC Decision rules could be represented as:

Given B_y > Bpa,

- If $F_{y-1} \leq F_{MSY}$, then apply F_{MSY}, conditional on $1.15\ TAC_{y-1} \geq TAC_y \geq 0.85\ TAC_{y-1}$

•	If $F_{pa} > F_{y-1} > F_{MSY}$, then apply the maximum of F_{MSY}:F_{y-1}, given the conditions that 1.15 $TAC_{y-1} \geq TAC_y \geq 0.85\ TAC_{y-1}$ and F must not increase.

Finally,

•	If ($F_{y-1} > F_{pa}$ or $B_y < B_{pa}$), then apply an F that meets the condition ($F_y \leq F_{pa}$ and $B_{y+1} \geq B_{pa}$) conditional on $1.15TAC_{y-1} \geq TAC_y \geq 0.85\ TAC_{y-1}$ unless this leads to ($F_y > F_{y-1}$ or $B_{y+1} < B_y$) in which case adjust F until ($F_y \leq F_{y-1}$ or $B_{y+1} \geq B_y$).

3.2. Initial Conditions

The terms of reference specify three TAC decision rules to be applied to populations determined to be in three different conditions;

•	Stocks exploited consistently with Maximum Sustainable Yield.

•	Stocks overexploited with respect to maximum sustainable yield but inside safe biological limits.

•	Stocks outside safe biological limits.

Stock data consistent with these conditions were generated for use in the TAC decision rule testing phase of the work.

3.2.1. Biological characteristics of 3 example populations

Three simulated populations were generated based on three species with different life histories. A codoid population, based on North Sea cod data, a hakeoid population, based on Northern hake, and a heroid, based on North Sea herring. Data on biological parameters were obtained from the relevant ICES Working Groups. The simulated populations are not intended to represent any single stock but to provide a series of different settings for testing the TAC decision rules.

Two scenarios of stock-recruitment relationships were devised for each species: high and low productivity represented by the steepness of the stock/recruitment relationship. For the codoid and hakeoid stocks these were represented by values of 0.6 and 0.9 for the steepness parameter of a Ricker stock-recruit function

$$R = aSe^{-bS}$$

where the a and b parameters have been expressed in terms of steepness (z), recruitment at equilibrium (R_0), and spawner biomass per recruit ($\tilde{S}$) (Michielsens & McAllister, 2004)

$$z = .2(\tilde{S}a)^{.8}$$

$$S_0 = 4\frac{\log(\tilde{S}a)}{b}$$

Although the interpretation of these parameters is more controversial for the Ricker stock-recruit function, it allows for scenarios to be formulated with a clearer biological basis.

Stock-recruitment for the heroid stock was modelled following a Beverton & Holt model,

$$R = \frac{\alpha S}{\beta + S}$$

where the parameters were reformulated in terms of steepness (z) and virgin biomass (S_0)

$$z = \frac{\alpha\tilde{S}}{4\beta + \alpha\tilde{S}}$$

$$S_0 = \frac{\tilde{S}\alpha(5z-1)}{4z}$$

The data years used to perform the fit were

codoid: 1963-2004

hakeoid: 1978-2005

heroid: 1960-2004

Natural mortality at age (M_a) and maturity at age were taken from the relevant ICES Working Groups. Weights at age and selection at age were derived as averages over the entire time periods from the working group estimates. All vectors were treated as time-invariant.

3.2.2. Simulation approach

Initial conditions were generated according to three scenarios

- Scenario 1: Stocks exploited consistently with maximum sustainable yield
- Scenario 2: Stocks overexploited with respect to maximum sustainable yield but inside safe biological limits
- Scenario 3: Stocks outside safe biological limits

For each stock and recruitment steepness assumption

- Long-term equilibrium values of yield and SSB were determined for a range of F values using the R package FLBRP. This provided an F value giving maximum sustainable yield (F_{MSY}) and the corresponding SSB (B_{MSY}).
- Fifty repetitions of a time series of the stock were generated over the same years used to fit the stock recruitment relationship. Each repetition had a stock biomass starting value equal to the historical data value for the initial year.
- Levels of fishing mortality (F) were fixed in each of three scenarios.
    - F_{MSY} for scenario 1
    - $1.5*F_{MSY}$ for scenarios 2 and 3
- Uncertainty was introduced in the stock-recruitment relationship by re-sampling with replacement from the lognormal residuals of the estimated stock recruitment model. Consequently, the age compositions in the final years varied among the replicates and none of the simulated populations were at equilibrium.

To generate a stock conforming to scenario 2, recruitment was increased relative to that obtained from the normal stock recruitment fit as follows. A recruitment value was generated in the usual way, i.e. $R = \hat{R} + \varepsilon$ where $\hat{R}$ is the value given by the stock-recruit relationship and ε is a random error term. The following ratio was then calculated

$$\rho = \frac{R}{\hat{R}}$$

The initial recruitment value was then replaced with a value given by

$$R = \hat{R} e^{2*\rho}$$

this replacement value is always greater than the value derived from the fitted stock-recruit relationship.

This increased recruitment was applied at the end of the initialisation phase over a number of years equal to the number of ages in the stock, in order for the increase in numbers at age to be represented at all ages[1].

The populations were projected following the usual survival equation,

$$N_{a+1,y+1} = N_{a,y} e^{-Z_{a,y}}$$

where Z = F + M. The catches given the assumed fishing mortality are given by

$$C_{a+1,y+1} = N_{a+1,y+1} * \frac{F_{a+1,y+1}}{Z_{a+1,y+1}} (1 - e^{-Z_{a+1,y+1}})$$

The uncertainty introduced in the stock-recruitment relationship led to varying age distributions and SSB during the initialisation time series. Because fishing mortality was held constant during this phase catch totals tracked the variations in exploitable biomass. The end points of these time series were used as the initial starting values of the ‘forward simulations’ used to test the TAC decision rules. A single forward projection was performed from each initial start point.

Multiple repetitions of the initialisations were performed to allow the variability in stock level around the mean equilibrium level (as caused by the random variation in recruitment) to be captured in the starting values used by the forward simulations. If this was not done there would be initial years in the forward simulation that did not reflect the variability of outcomes using the TAC decision rule under test. If additional sources of noise were introduced into the forward projections it may be necessary to increase the number of projections. This could be done by running multiple repetitions from each forward projection start point.

[1] For the codoid stock there were 15 ages but the initial conditions dataset received increased recruitment over the final 7 years. This was because the codoid stock originally contained 7 age classes.

The number of years used in the initialisation time series was longer than was necessary to account for recruitment variability. However, the longest time series possible was used to be sure a steady state was obtained and to allow for incorporation of a VPA style stock assessment algorithm to perform the assessment part of the forward simulation. The probability of successful convergence of these algorithms was increased with longer time series.

3.2.3. Summary of initial conditions

A summary of the initial conditions of the three generic stocks are given in Tables 3.1 to 3.6. Box and whisker plots showing the distribution of annual recruitment, SSB, and the age composition in the final year of the intial conditions for the codoid stock with steepness of 0.6 are shown in Figure 3.5 – 3.7.

B_{pa} is defined as the spawning stock biomass at equilibrium corresponding to a yield which is one half of maximum sustainable yield (MSY). The precautionary fishing mortality (F_{pa}) was then defined as the fishing mortality (taken as a mean over all ages) that gave a yield of 0.5* MSY when the population is at B_{pa}.

S=0.6				S=0.9			
α	β	B_0		α	β	B_0	
6.345325	2.75E-06			10.53338	3.76E-06		
Ref points	F	SSB	Y	Ref points	F	SSB	Y
msy	0.52	472,138	416,644	msy	0.65	338,490	451,221
pa	0.78	116,250	208,322	pa	0.95	70,732	225,610
0.1	0.11	1,281,595	156,251	0.1	0.11	1,070,895	130,563
max	0.18	1,114,214	229,303	max	0.18	948,636	195,228
30%SPR	0.15	1,180,642	200,787	30%SPR	0.15	997,156	169,582
crash							

Table 3-1 : Ricker stock-recruitment parameter values and equilibrium values of F, SSB and yield for the codoid stock.

Age	s	M	W (kg)	m
1	0.4	0.8	0.355	0.01
2	1	0.35	0.819	0.05
3	0.98	0.25	2.09	0.23
4	0.86	0.2	3.976	0.62
5	0.78	0.2	6.203	0.86
6	0.77	0.2	8.309	1
7	0.77	0.2	9.963	1
8	0.76	0.2	11.114	1
9	0.8	0.2	12.454	1
10	0.87	0.2	13.493	1
11	1	0.2	14.07	1
12	0.76	0.2	15.212	1
13	0.76	0.2	17.051	1
14	0.76	0.2	17.986	1
15	0.76	0.2	17.333	1

Table 3-2 : Biological parameter values for the codoid stock.

S=0.6				S=0.9			
α	β			α	β		
3.11	3.92E-06			5.158623	5.37E-06		
Ref points	F	SSB	Y	Ref points	F	SSB	Y
msy	0.18	282,800	71,761	msy	0.24	234,872	80,308
pa	0.33	87,180	35,880	pa	0.45	58,821	40,154
0.1	0.11	391,405	64,393	0.1	0.11	380,243	62,557
max	0.15	333,745	70,077	max	0.15	338,127	70,998
30%SPR	0.14	346,823	69,124	30%SPR	0.14	347,680	69,295

Table 3-3 : Ricker stock-recruitment parameter values and equilibrium values of F, SSB and yield for the hakeoid stock.

Age	s	M	W (kg)	m
0	0	0.2	0.0261	slot
1	0.27	0.2	0.0804	0
2	0.46	0.2	0.1827	0
3	0.58	0.2	0.3363	0.23
4	0.57	0.2	0.5587	0.6
5	0.63	0.2	0.8643	0.9
6	0.78	0.2	1.2186	1
7	1	0.2	1.6056	1
8	1	0.2	2.6399	1

Table 3-4 : Biological parameter values for the hakeoid stock.

S=0.4				S=0.7			
α	β			α	β		
18376	4.00E+01			12863	4.80E+01		
Ref points	F	SSB	Y	Ref points	F	SSB	Y
msy	0.14	982	187	msy	0.21	544	159
pa	0.43	134	94	pa	0.83	44	80
0.1	0.13	1072	187	0.1	0.13	870	152
max	0.31	322	144	max	0.31	345	154
30%SPR	0.13	1043	187	30%SPR	0.13	850	153

Table 3-5 : Beverton-Holt stock-recruitment parameter values and equilibrium values of F, SSB and yield for the heroid stock.

Age	s	M	W (kg)	m
0	0.16	1.0	0.012	0
1	0.37	1.0	0.051	0
2	0.58	0.3	0.141	0.816
3	0.73	0.2	0.183	0.966
4	0.74	0.1	0.220	1
5	0.73	0.1	0.238	1
6	0.74	0.1	0.269	1
7	0.84	0.1	0.291	1
8	1	0.1	0.302	1
9	1	0.1	0.317	1

Table 3-6 : Biological parameter values for the heroid stock.

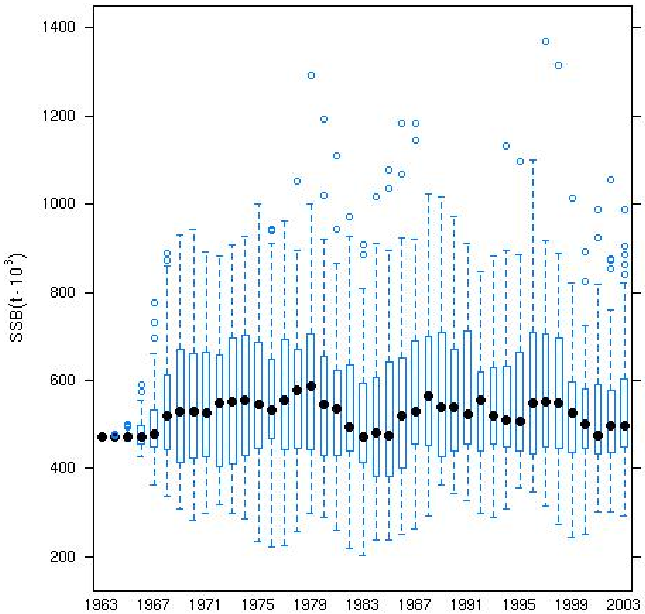

Figure 3.5: Box and whisker plots showing the annual distributions of SSB for the initial conditions for the codoid stock with steepness of 0.6.

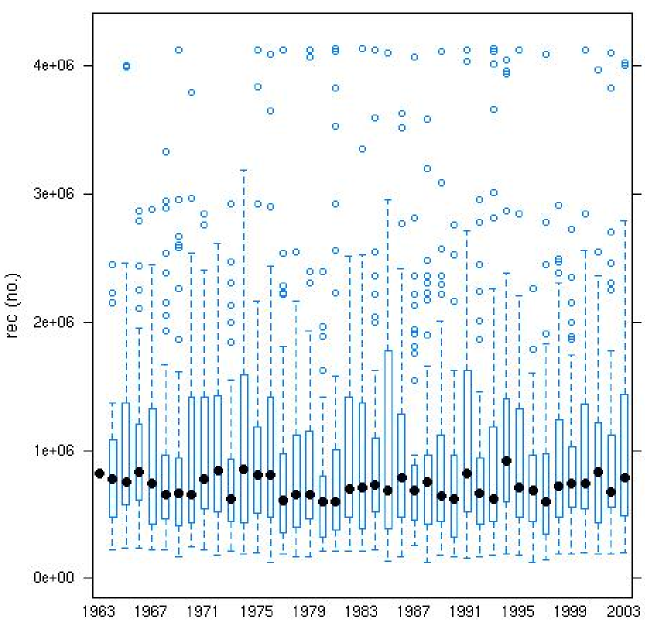

Figure 3.5: Box and whisker plots showing the annual distributions of recruitment for the initial conditions for the codoid stock with steepness of 0.6.

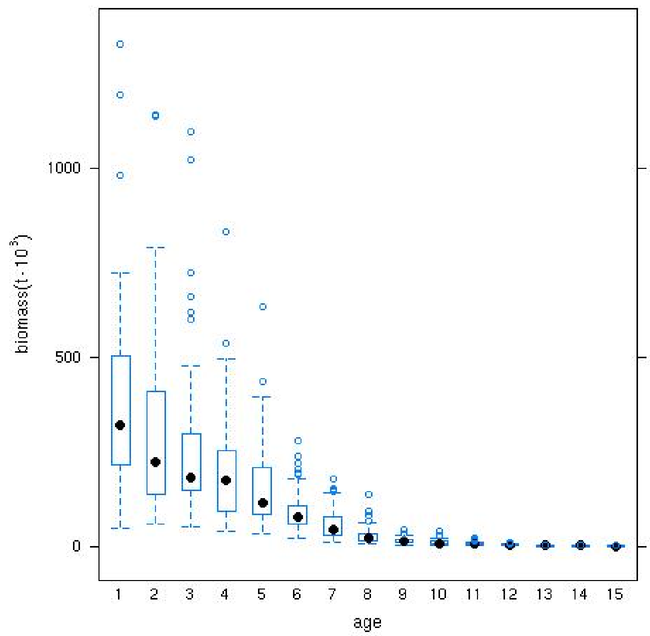

Figure 3.5: Box and whisker plots showing the distributions of numbers at age in the final year of the initial conditions for the codoid stock with steepness of 0.6.

3.3. Management Procedure simulation

Three computer applications were used to test the TDRs: FLR, SMS, and Visual Basic. This section describes the individual applications. There was not enough time to complete all tests during the meeting and additional work is required. The methods described here provide guidance for future work, but the working group may decide to modify methods as more experience is gained.

It was agreed to use two approaches to test the TDR performance. In the first approach, the individual rules were tested beginning with simulated data reflecting starting conditions corresponding to the three individual rules. There was no consideration of changes in stock condition during the simulations and the same rule was applied regardless of any change in condition. Consequently, the performance of the rules needs to be considered over the medium term of approximately 5 years from the start of the forward simulation, a period over which one could assess whether the desired effects of the rules were realized. The second approach used a combined rule and included an evaluation of the status of the stock each year. The simulations were started from the 3 starting conditions described above, but stock status was determined each year and the appropriate rule was applied. In this case, longer term performance over approximately 30 years was considered.

3.3.1. Implementation in FLR

A numerical simulation model was developed during the meeting to model the interplay between the biological dynamics of the stocks the dynamics of the fleet, the perception of the stock status via an assessment and a management measure resulting in a harvest control rule that acts on the fishery   A relational diagram of the -full feedback- model is given in Figure 3.8.

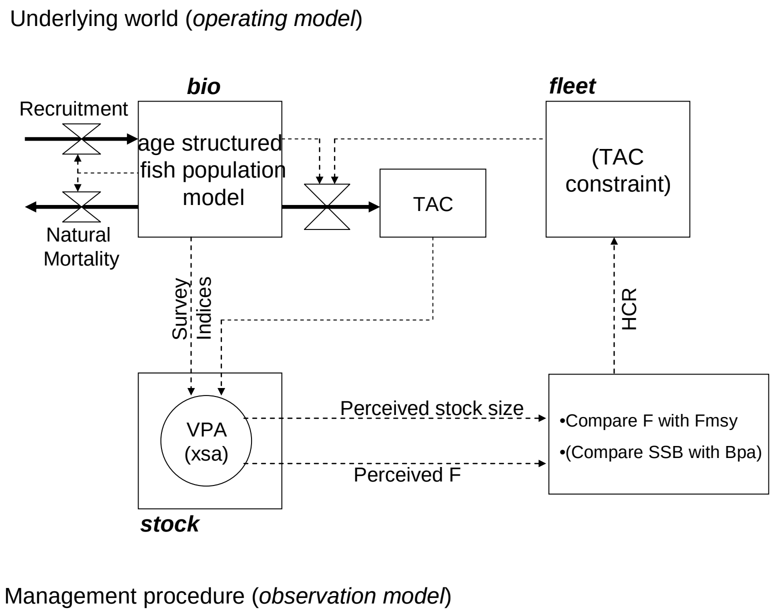

Figure 3.8: Relational diagram of the FLR model

Biological operating model

The biological operating model consisted of an age structured population state of a 'real' stock, including the population dynamics of this stock. The spawning stock biomass (SSB), the biomass of the sexually mature part of the population, determines the number of recruits of the next year class. Two Ricker type relations are chosen differing in steepness. The stock numbers at age are affected by natural mortality set for every age class, and fishing mortality. As mentioned earlier, the model was initialised using a simulated population that had been created under a number of initial exploitation scenarios; exploitation at F_{MSY}; exploitation at 1.5 times F_{MSY}, and exploitation at 1.5 times F_{MSY} with increased recruitment in the most recent years (see section 3.2 on initial conditions).The simulation was initiated in 2004. Catch and survivors of the stocks were then calculated for the successive years given these (natural & fishing) mortality rates. From 2005 onwards the simulation continued with recruits sampled from the stock-recruitment relationship, given the stock sizes.

Fleet characteristics and fishery

The operating model comprised an underlying biological population and a fleet component to extract catches from the population. However, for the initial model constructed during this meeting, observation error and implementation error were not explicitly considered and the fleet component has been omitted. It has been assumed that catches are observed without error and that the fishing mortality and selection pattern applied to the underlying population was determined precisely by the assessment process. Future developments of the model should incorporate a feet component into the operating model so that the potential effects of observation error and implementation bias can be explored.

Assessment and forecast observation model

The “perceived” stocks status was generated through the explicit inclusion of a stock assessment in the simulation. Catches of the fleet were recorded. A survey fleet was simulated assuming a constant fishing effort and a scalar catchability such that the survey index was proportional to stock abundance. For the FRL implementation, the assessment method used was XSA based on catches and the survey index. Biological parameters of the stocks in the assessment process were assumed to be equal to the biological parameters set in the operating model, i.e. they were assumed to be constant and known without error.

In order to set a TAC for year y, assessment data were available up to year y-2 and the assessment itself is carried out in year y-1. The stock assessment produced fishing mortality estimates up to year y-2, and beginning of year population estimates up to year y-1. The recruitment used for projections was the geometric mean recruitment computed over the "observed" time period, all the biological parameters were fixed (as simulated), F for projection was the y-2 estimate over the complete age range.

In the management part of the model, estimated fishing mortality (F) and stock biomass were used as input to formulate advice for setting the TACs, and simulate a TDR. The results of the TDR procedure in terms of TAC (or F-level) affected the removals of catch from the population during the year in which the TDR was implemented. Under the assumption of no observation error and no implementation error, it was assumed that the catches removed from the population exactly matched the TAC.

Simulation runs

The simulations were run with process error introduced in the population biology via random noise around the stock-recruitment relationship. Other biological parameters such as maturity, weight at age, natural mortality were held constant throughout the simulation.

A number of simplifying assumptions have been made:

- The fishery was single species fishery

- All catches were made by one fleet

- Catchability by the survey was constant;

- Future recruitment was related to stock size in the operational model by the Ricker stock-recruitment relationship;

- Catches and the biological parameters weight at age, M at age, maturity at age, and selectivity at age were assumed to be known without error.

3.3.2. Implementation in SMS

The evaluation was done using the SMS (**S**tochastic **M**ulti **S**pecies model; Lewy and Vinther, 2004) assessment model and forecast. Details of the SMS implementation of Harvest Control Rules simulations can be found in ICES, 2006.

Basically the method mimics that decisions on e.g. TAC are taken on the basis of imperfect knowledge (equivalent to stock numbers estimated from stock assessment) (Figure 3.9). The approach does not simulate the full annual cycle of assessment and projection. Instead, it is assumed that the true stock size can be "observed" with some bias and noise and it is this "perceived" stock that makes the basis for the use of TDR and estimation of a TAC. The true stock size is assumed known in the first projection year and is later updated annually by recruitment and true catches derived from application of TDR on the "perceived" stock.

Overview of methodology

An overview of the simulation methodology is presented below.

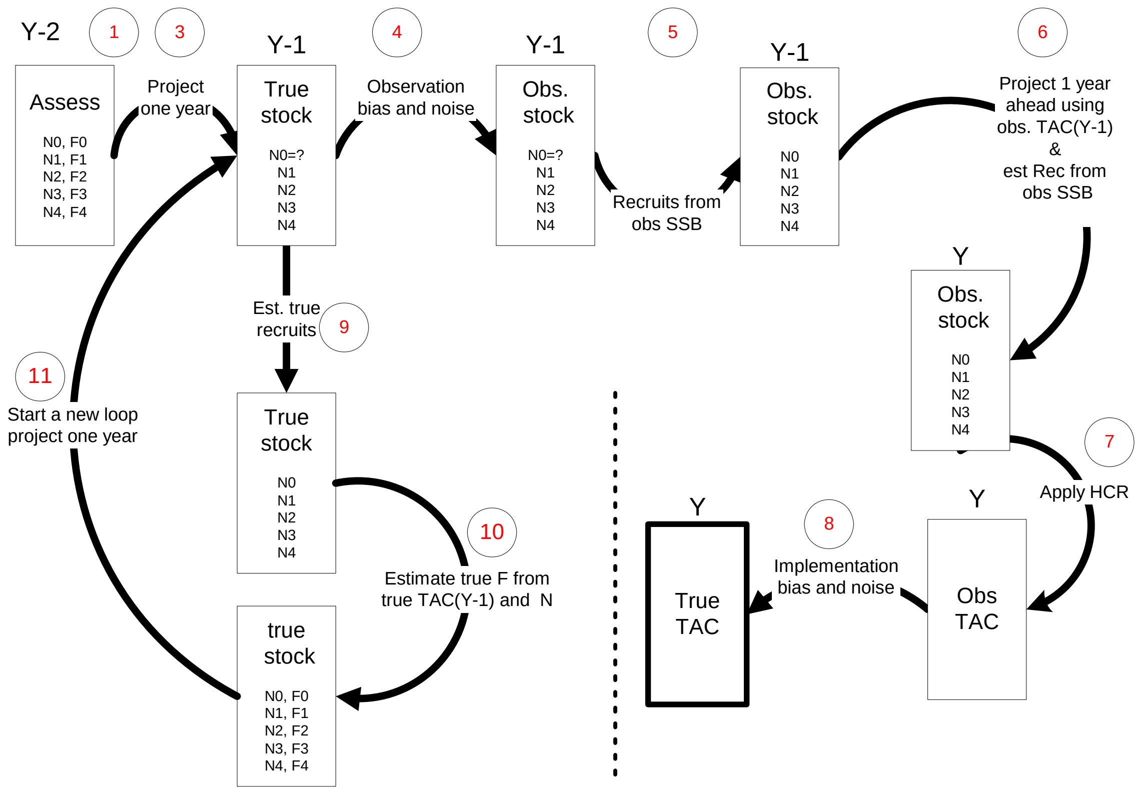

Figure 3.9 Overview of SMS HCR evaluation methodology. Numbers in circles refer to annotated text below.

1. Make an assessment with terminal year Y-2 to estimate “true” stock numbers

2. Increase year by one: Year=Y-1

3. Project true stock numbers to 1. Jan year Y-1

4. Put noise and bias on true N(Y-1) to produce observed N(Y-1) (this simulates an assessment)

5. Estimate observed recruits from observed SSB and “true” SSB-R relation applied without noise

6. Project observed N(Y-1) to N(Y) using observed TAC(Y-1, fixed exploitation pattern and recruitment from true SSB-R relation

7. Apply TDR to estimate observed TAC(Y)

8. Apply implementation bias and noise to calculate true TAC(Y)

9. Estimate true recruits(Y-1) from true SSB-R relation and uncertainty

10. Estimate true F(Y-1) from true N(Y-1) and true TAC(Y-1). Optionally adjust true TAC(Y-1) with cap F before this calculation.

11. go to 2

Simulations were one for each of the 50 initial populations (see section on initial conditions). Recruits were produced from the Ricker function and estimated parameters (see section xx) with variability estimated from a log-normal distribution using the estimated standard deviation from the original data fit. F_{SQ} was used for the first two years of the projection where after F was derived from the TDR.

3.3.3. Implementation in Visual Basic

Simulations were formulated in Visual Basic for Applications within Microsoft EXCEL. Spreadsheets were used as input forms specifying population parameters, such as age dependent parameters (weight in the stock, weight in the catch, weight in the discard, natural mortality and maturity) and starting population size and selectivity (fishing mortality and discard ogive), and as output forms of the model results. The input forms also set the management references used: F target (F_{MSY}), F_{pa} and B_{pa}.

The cod like population was chosen as an example; the reference starting year is set as 2004. Starting parameters are given in Table 3.7.

The recruitment simulations were based on a Ricker function:

R=a*SSB*exp(-SSB/k),

where R is the recruitment (in thousands), SSB represents the spawning stock biomass, a is the slope and k the carrying capacity (maximum SSB).

There was a random (Monte Carlo) variation in the estimated recruitment allowed at each SSB estimate. The random variation of recruitment was constrained at the upper and lower range by the CV as estimated from the standard deviation and the mean recruitment observed.

R is a random value between Rmin=R-R*CV and Rmax=R+R*CV

However, the recruitment was not allowed to be lower than the lowest value observed in the simulated stock. This model covered 90% of the observed recruitment variation. The 10 %

outliers represent extremely high and unlikely recruitment values at SSB below the carrying capacity.

The model framework consisted of a deterministic short term prediction procedure which was carried forward for 30 years. Beginning with the starting year population in 2004, the stock and catch were projected under status quo fishing mortality to the start of 2005, the year for which the TAC was to be set. The TAC calculation in 2005 was based on the construction of a management table specifying fishing mortality and catch in 2005 as a function of a multiplier on fishing mortality. The resulting stock size in the beginning of 2006 was also estimated and expressed as SSB, together with the corresponding fishing mortality in 2006. This procedure was then carried forward into the future by means of recruitment simulation and resetting the starting year and population. The model formulations foresee a record of each year's stock parameters and management decisions taken before the TAC year. Most parameters were allowed up to ±10% random variation at each starting year.

The full suite of 3 TDRs as given in COM(2006) 499 final and described in section 3.1 has been translated into Visual Basic code and applied for 100 iterations under 3 different starting conditions. The correctness of the translation is still under review through further simulation runs. Thus, any results presented here are purely of illustrative purposes and should not in any case be used as a basis for management advice.

The 3 different scenarios, in which the 3 TDRs are tested differ in the size of the starting population, fishing pressure and the slope of the Ricker recruitment and function, which represents recruitment variation. They can be summarised as:

- Scenario 1: starting stock size at B_{MSY}, starting fishing mortality below F_{pa}, Ricker slope at a=6.0 (R= 6.0*SSB*exp(-SSB/600,000). The stock and its exploitation can be considered almost consistent with MSY (Figure 4.9).

- Scenario 2: starting stock size at B_{MSY}, starting fishing mortality below F_{pa}, Ricker slope at a=9.0 (R=9.0*SSB*exp(-SSB/600,000). The stock and its exploitation can be considered almost consistent with MSY. However, the higher Ricker slope indicates favourable reproductive potential (Figure 4.10).

- Scenario 3: starting stock size below B_{pa}, starting fishing mortality equals 1.3*F_{MSY}, Ricker slope at a=6.0 (R= 6.0*SSB*exp(-SSB/600,000). The stock is at risk of reduced reproduction and overfished under normal reproductive potential (Figure 4.11).

Table 3.7 Parameters of the cod like starting population and selection (shaded fields are to be changed dependent of the stock and its fishery in the starting year).

min age	max age	age group	stock weight (kg)	catch weight (kg)	landing weight (kg)	discard weight (kg)	discard rate	prop. mature	F	M	stock (000)		
1	15	1	0.355	0.355	0.622	0.277	0.773	0.010	0.338	0.800	1291561	Ricker a	6
		2	0.819	0.819	0.974	0.391	0.266	0.050	0.848	0.350	412446	Ricker k (t)	600000
min Fref	max Fref	3	2.090	2.090	2.129	0.471	0.024	0.230	0.833	0.250	124165	5 % quantile recruitment (minimum)	114034
2	4	4	3.976	3.976	3.978	0.016	0.001	0.620	0.730	0.200	42033	recruitment relative variation CV	0.600
		5	6.203	6.203	6.207	0.054	0.001	0.860	0.660	0.200	16571	B constraint (t)	200000
year	2004	6	8.309	8.309	8.313	0.068	0.000	1.000	0.655	0.200	6997	rel. min. SSB increase if SSB<B constraint	0.300
		7	9.963	9.963	9.966	0.085	0.000	1.000	0.655	0.200	2950	F constraint	0.900
		8	11.114	11.114	11.118	0.120	0.000	1.000	0.648	0.200	1247	F target	0.650
		9	12.454	12.454	12.454	0.000	0.000	1.000	0.679	0.200	533	rel. min. annual reduction in Fref	
		10	13.493	13.493	13.493	0.000	0.000	1.000	0.743	0.200	221	rel. max. annual change TAC +-	0.150
		11	14.070	14.070	14.074	0.137	0.000	1.000	0.851	0.200	86		
		12	15.212	15.212	15.212	0.000	0.000	1.000	0.651	0.200	30		
		13	17.051	17.051	17.051	0.000	0.000	1.000	0.651	0.200	13		
		14	17.986	17.986	17.986	0.000	0.000	1.000	0.651	0.200	5		
		15	17.333	17.333	17.333	0.000	0.000	1.000	0.651	0.200	2		
CV			0.10	0.10	0.10	0.00	0.00	0.10	0.00	0.10	0.00		
rel. bias									0.00		0.00		

3.4. Performance Measures

The following performance measures for each scenario were requested in the TOR; appropriate percentiles (e.g. 5th, 25th, 50th, 75th and 95th.) of fishing mortality relative to F_{MSY} and to $F_{0.1}$, biomass relative to B_{MSY}, yield relative to yield in the starting conditions, and recruitment levels. The working group was encouraged to provide a wide-ranging exploration of the issue and to report in appropriate detail.

4. PERFORMANCE OF TAC SETTING RULES

4.1. SMS evaluation of TDR for stocks exploited consistently with Maximum sustainable yield.

The trajectories of the 50 initial populations (data set codoid.a.9) are shown on Figure 4.1. Due to the limited number of initial populations, all the metrics (SSB, yield, mean F and recruits) varied a lot from year to year. The spread of all metrics increased through time. For the first 5 years of the simulation, the median F and yield show a decreasing trend while SSB seem stable. Over the full period median F, yield and recruitment show a decreasing trend, while median SSB fluctuated around B_{MSY} with amplitude of around 200,000t. The 10% percentile of SSB goes below the Bpa proxy after around 5 years.

The distribution and cumulative probability of SSB, yield and mean F, together with the annual change in the same metrics are shown in Figure 4.2. Most of the year to year changes in yield are within the plus minus 15% range, however, in around 15% of the cases the 85% of previous year's yield could not be obtained due to low stock size and the upper band on F (Cap F=1.2). Around 25% of the cases have an increase in yield limited by the upper 15% constraint

The result of using 100 repetitions for each of 50 initial populations (Figure 4.3) show a smoother temporal trend of the metrics, but the overall picture is similar to the results of just applying one trajectory for each initial population.

To explore what causes the very high 90% percentile of SSB (> 2,500,000 tons) in Figure 4.1, two individual trajectories with a high SSB are presented in Figure 4.4. All the metrics show a clear example of a limit cycle scenario. This is due to the SSB-recruitment relation used in combination with a modestly high variance of recruitment (standard deviation at 0.47 in a log-normal distribution). For a high SSB the recruitment drops down to almost zero, which initiates a drop in SSB, imposed by an F much higher than F_{MSY} due to the TAC constraints. If there is no variance on the recruitment, the SSB remain below the 350,000 t and the four metrics stabilizes very fast (Figure 4.5).

Using a Ricker relation with a smaller steepness parameter (data set codoid.a.6) does not remove the limit cycles (Figure 4.6).

The problem is not the TAC constraints; it is the applied Ricker curve that creates the highly variable trajectories. Figure 4.7 present two trajectories where the TAC is estimated from a F_{MSY} and no TAC constraint is applied. Even though we use a constant F to set the TAC in the perceived system, the real F varies within the range 0.4 – 1.2. When the TAC is estimated, the recruitment is not known for the year of the TAC and for the preceding intermediate year. For the calculation of the TAC these recruits are estimated from the perceived stock and the SSB recruitment relation (without noise). However, because of the high F_{MSY} (0.652) the contribution to the catch from the two youngest age groups is significant. Recruits for the "true" stock are however, estimated taking the noise (0.47) into account, such that the TAC (derived from the "perceived" stock) might become very different from applying a fixed F on the "true" stock. Without the mis-estimation of recruits the system will, as expected, stabilize very fast (Figure 4.8).

To conclude: The presently used Ricker relation and the derived high F_{MSY} in combination with the uncertainty on the recruitment estimate create unrealistic results and the presented TDR evaluation can only be considered as a preliminary test example.

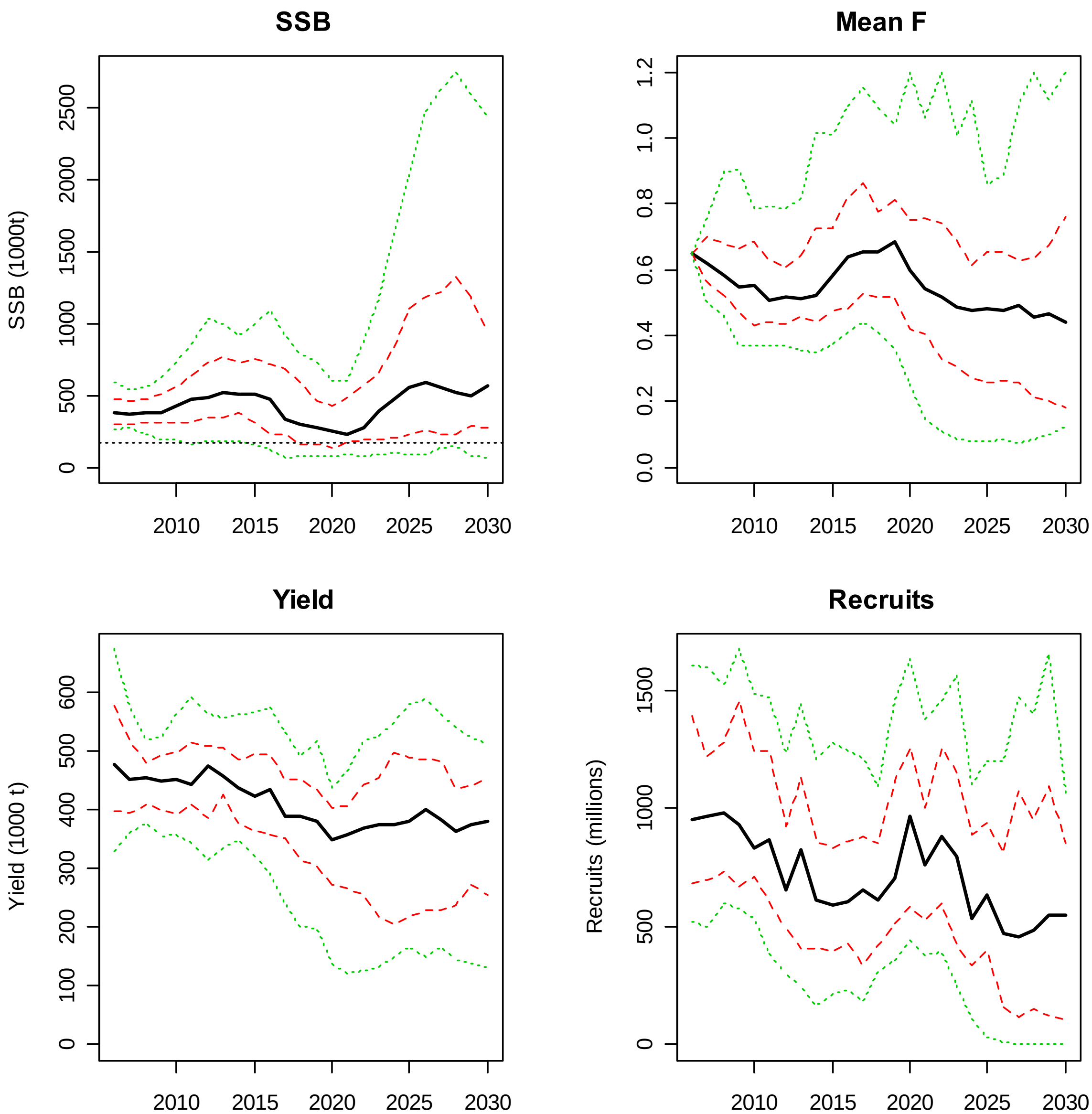

Figure 4.1. Trajectories of the 50 initial populations of the "codoid" with steepness parameter 0.9 (data set codoid.a.9) and application of the FMSY proxy and a constraint of +- 15% at TAC. The graphs show the 10, 25, 50, 75 and 90 percentiles values.

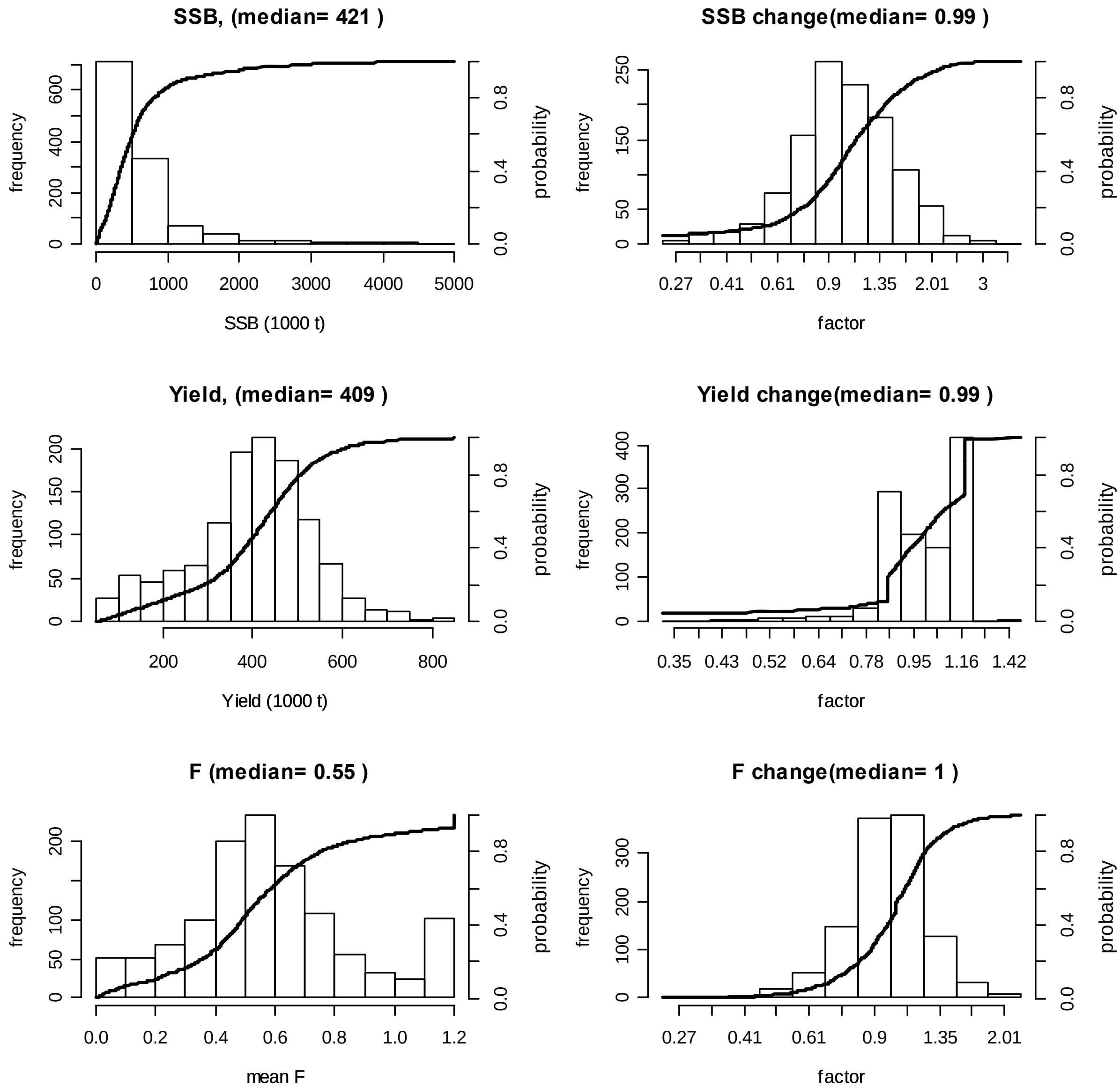

Figure 4.2. Distribution and cumulative probability of population metrics for the time series 2007- 2030. (data set codoid.a.9)

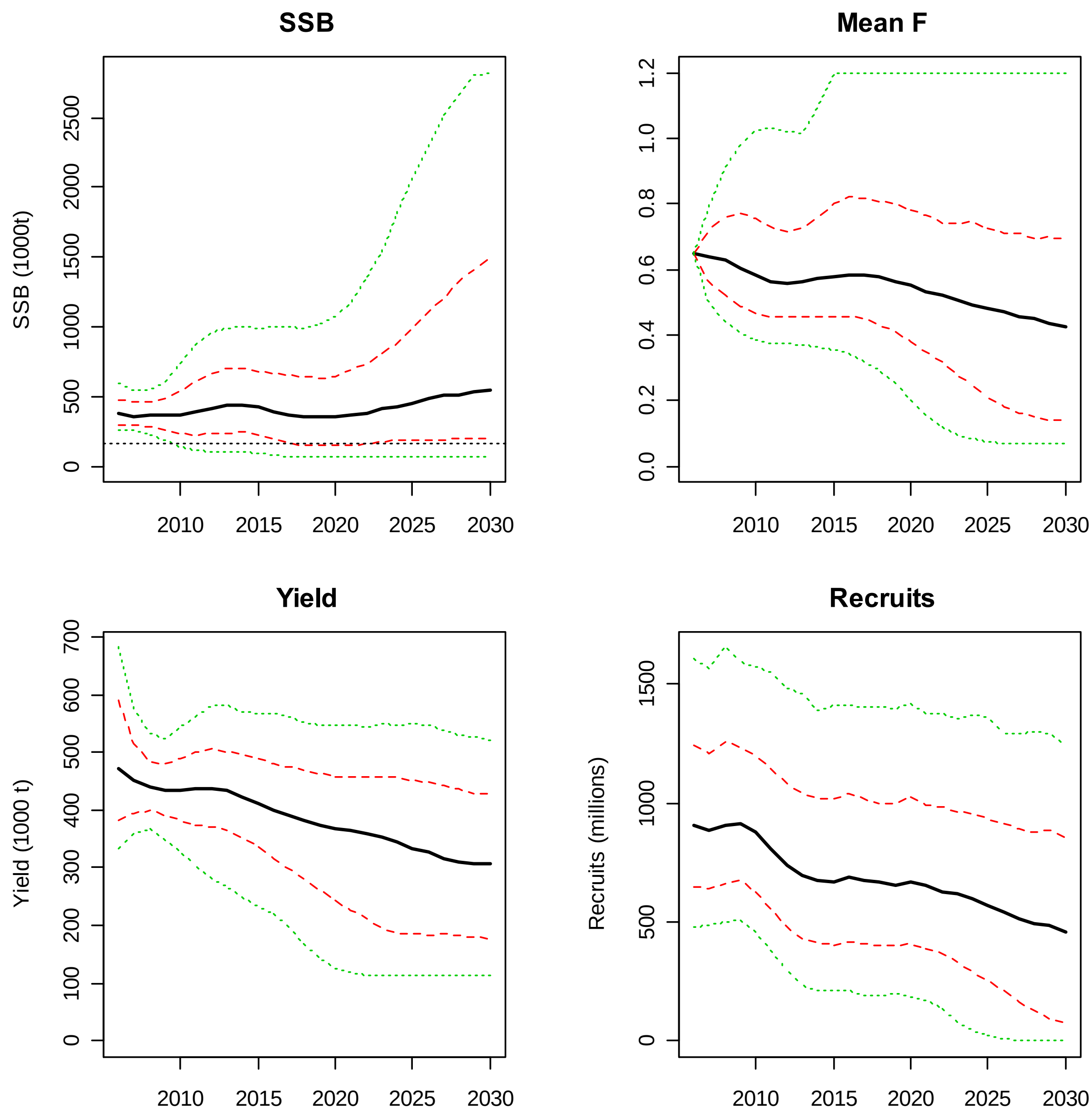

Figure 4.3. Trajectories of the 50 initial populations, each repeated 100 times, of the ”codoid” with steepness parameter 0.9 (data set codoid.a.9) and application of the FMSY proxy and a constraint of +- 15% at TAC. The graphs show the 10, 25, 50, 75 and 90 percentiles values.

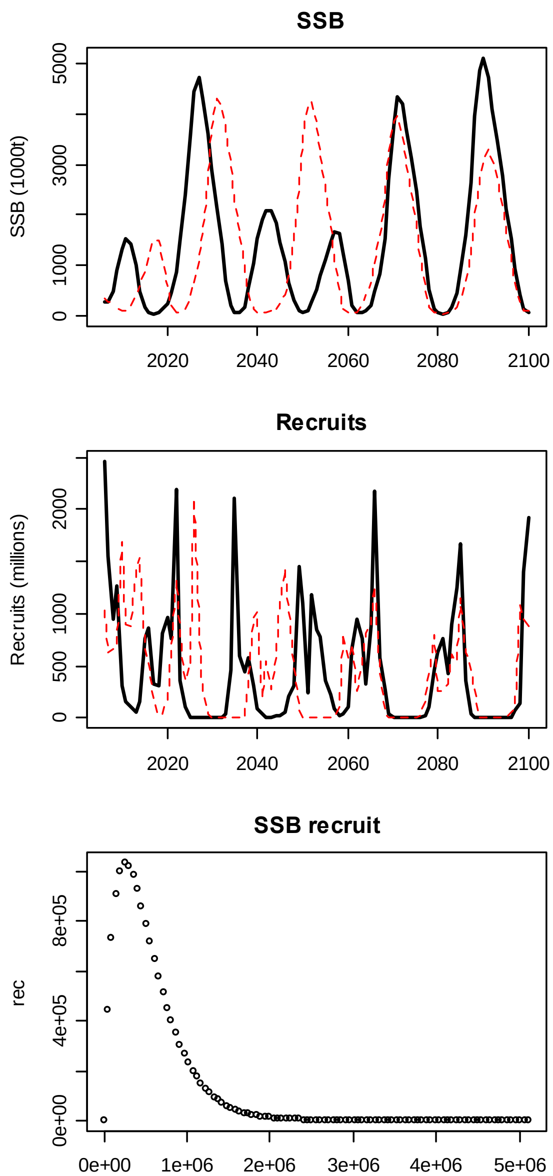

Figure 4.4. Trajectories of the 2 initial populations, of the ”codoid” with steepness parameter 0.9 (data set codoid.a.9) and application of the FMSY proxy and a constraint of +- 15% at TAC. The figure gives also the SSB-recruitment relation for the observed value of SSB.

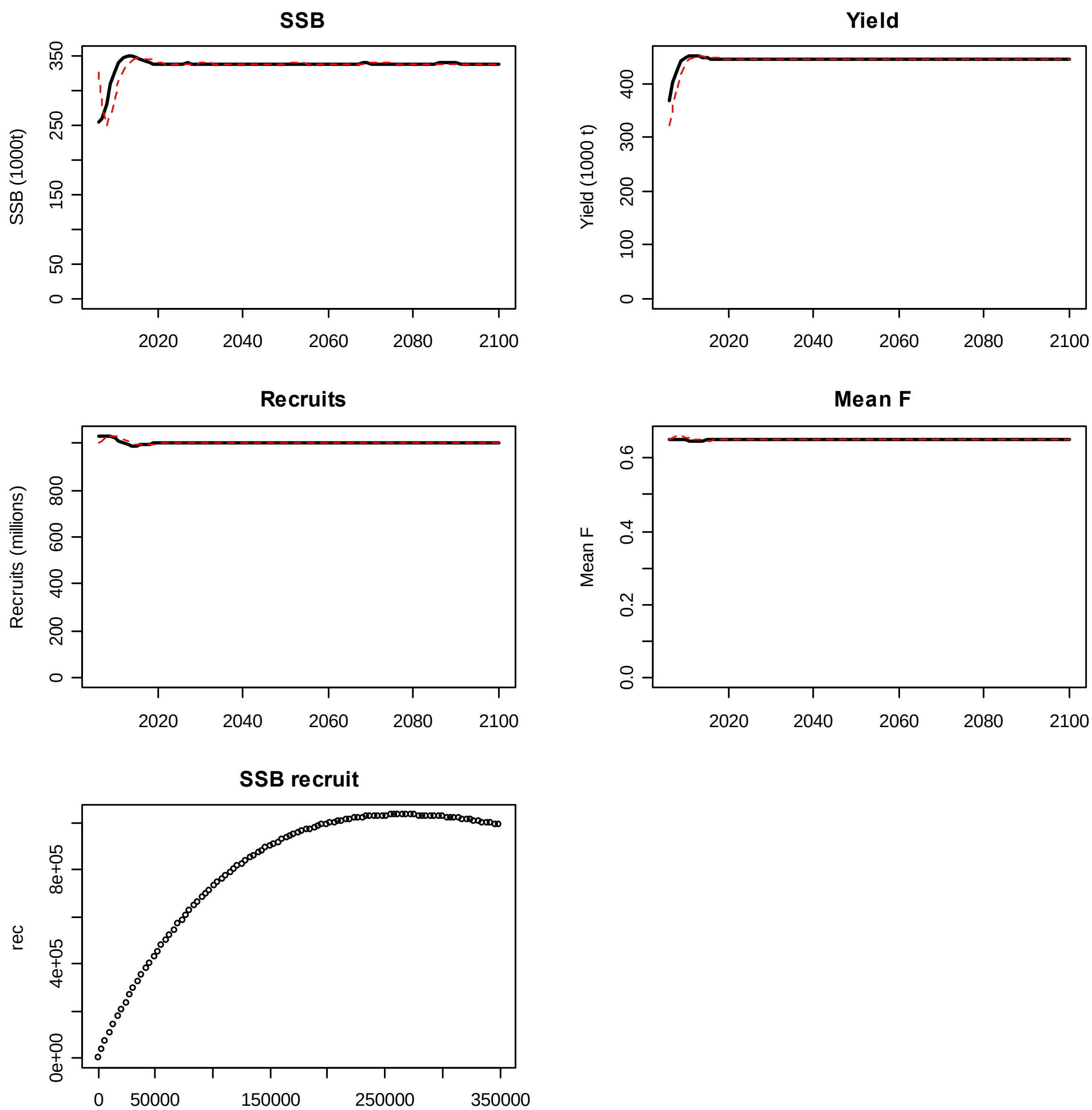

Figure 4.5 Trajectories of the 2 initial populations, of the ”codoid” with steepness parameter 0.9 (data set codoid.a.9) and application of the FMSY proxy and a constraint of +- 15% at TAC. The figure gives also the SSB-recruitment relation for the observed value of SSB. The recruitment is estimates from the Ricker relation assuming no variance.

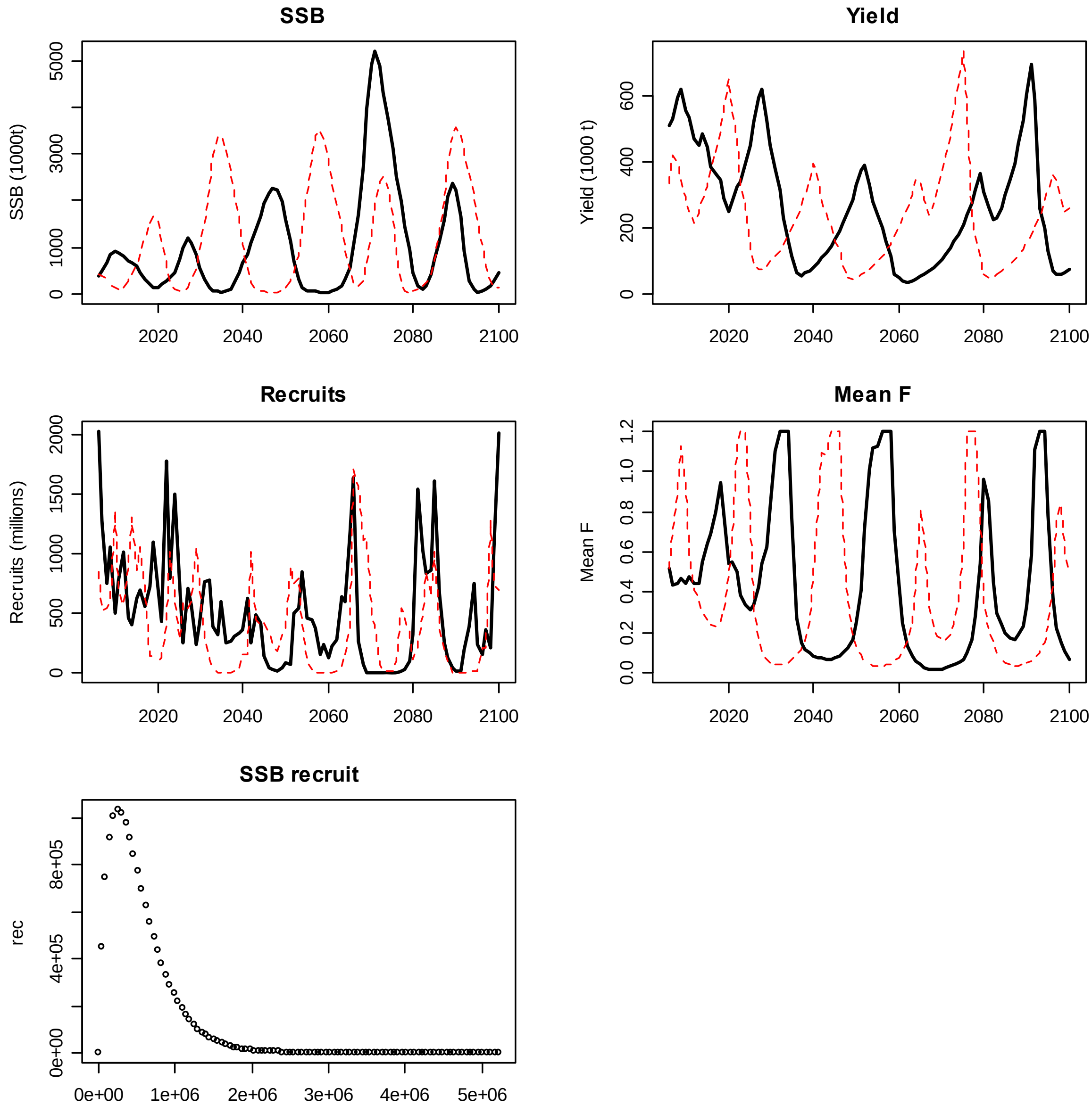

Figure 4.6 Trajectories of the 2 initial populations, of the "codoid" with steepness parameter 0.6 (data set codoid.a.6) and application of the FMSY proxy and a constraint of +- 15% at TAC. The figure gives also the SSB-recruitment relation for the observed value of SSB

Figur

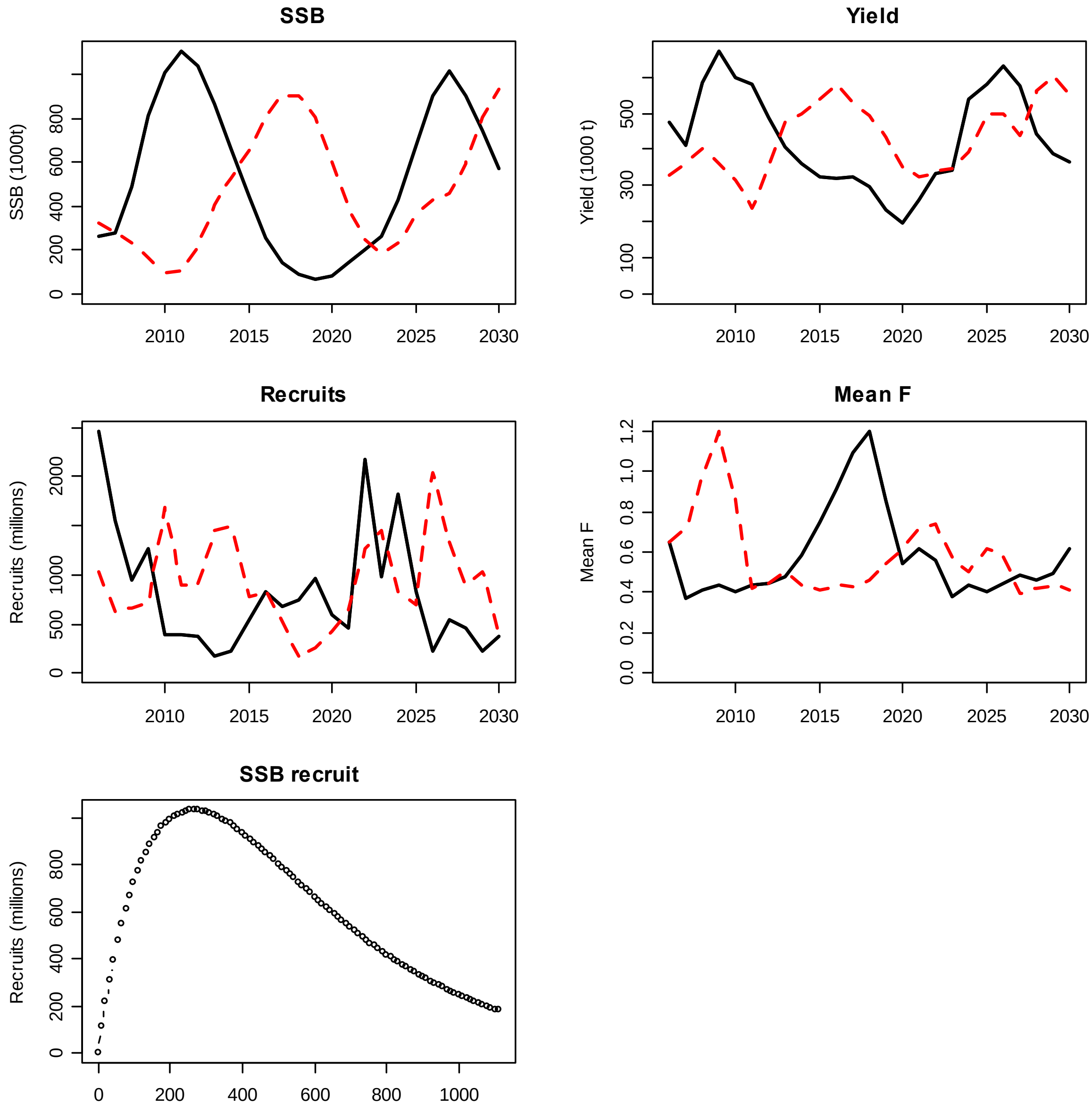

Figure 4.7 Trajectories of the 2 initial populations, of the ”codoid” with steepness parameter 0.9 (data set codoid.a.9) and application of the FMSY proxy and a NO TAC constraint. The figure gives also the SSB-recruitment relation for the observed value of SSB.

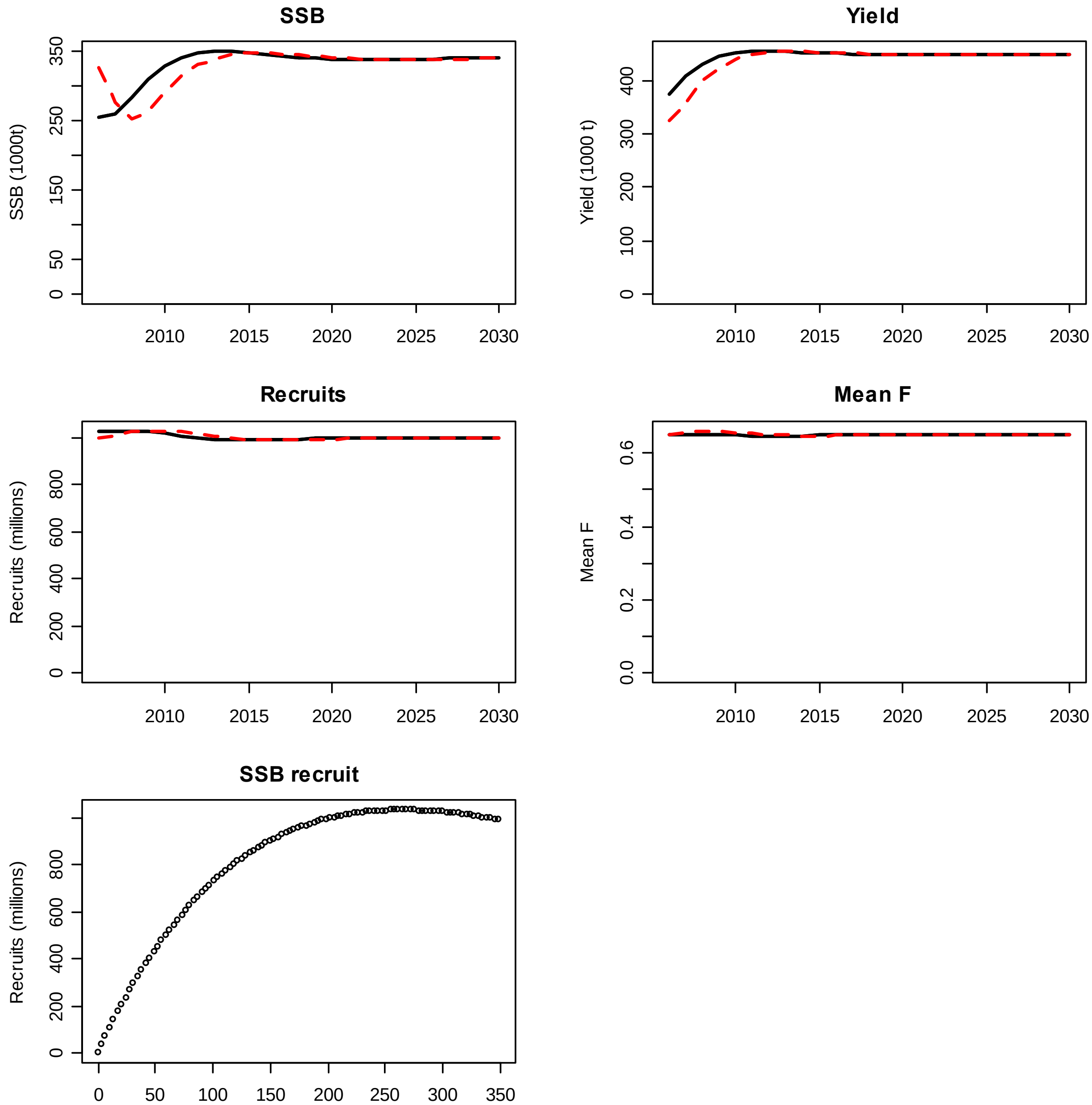

Figure 4.8. Trajectories of the 2 initial populations, of the "codoid" with steepness parameter 0.9 (data set codoid.a.9) and application of the FMSY proxy and a NO TAC constraint. The recruitment is produced with no noise. The figure also gives the SSB-recruitment relation for the observed value of SSB.

4.2. Stocks overexploited with respect to maximum sustainable yield but inside safe biological limits.

4.3. Stocks outside safe biological limits.

4.4. Combined analysis where stock condition changes during simulation

The results of each scenario tested with the Visual Basic application are shown in Figures 4.9 – 4.11. The results of scenario 1 indicate relatively stable conditions in the stock and TAC, starting from a healthy state and being exploited at levels considered sustainable. There seems to be the tendency for a slight reduction in fishing mortality towards F_{MSY}. There are no indications for strong management actions, as the stock stays at high production levels, even the constraint of the annual TAC variation being constrained to a maximum of ±15% appears to be imposed rarely.

As could be expected from an increased recruitment potential, scenario 2 indicates a 40% higher sustainable exploitation level as compared with the normal recruitment. The higher TACs are achieved through the management decisions within the first decade after the starting year 2004. The time of about 10 years until the higher sustainable level is achieved is determined by management decisions which appear mostly to be constrained by the upper 15% TAC change rule. After 10 years, the situation appears quite stable without a high risk for the stock or its fishery.

In contrast to scenarios 1 and 2, the poor starting conditions of the stock in scenario 3 in terms of low stock size and high fishing pressure immediately required strong management actions in accordance with the TDRs. For the first year 2005 following the starting year 2004 the lower -15% TAC change rule could not be implemented and was overruled to keep the SSB at least constant. The following 3 stock recovery years would then be mainly dominated by the lower -15% rule. After the stock recovery, the management is constrained to only change the annual TACs by a maximum of 15%. This implies a high growth potential of the stock far beyond historically recorded levels, complemented by high reductions in fishing mortality and discards, the latter being a result of increased mean weight of the fish in the stock. The high stock size will create very low recruitment which then forces the stock to decrease again. After a period of 20 years, the dynamics of the stock and fishery are smoothed by the management decisions towards the level seen in scenario 1.

Note: there is hope that the model is doing what we want it to do! At least the stock conditions and management actions at the end of the prediction period appear quite similar!

Next steps: Check further the rules by more simulations under different starting conditions.

Check another recruitment model, especially Beverton&Holt.

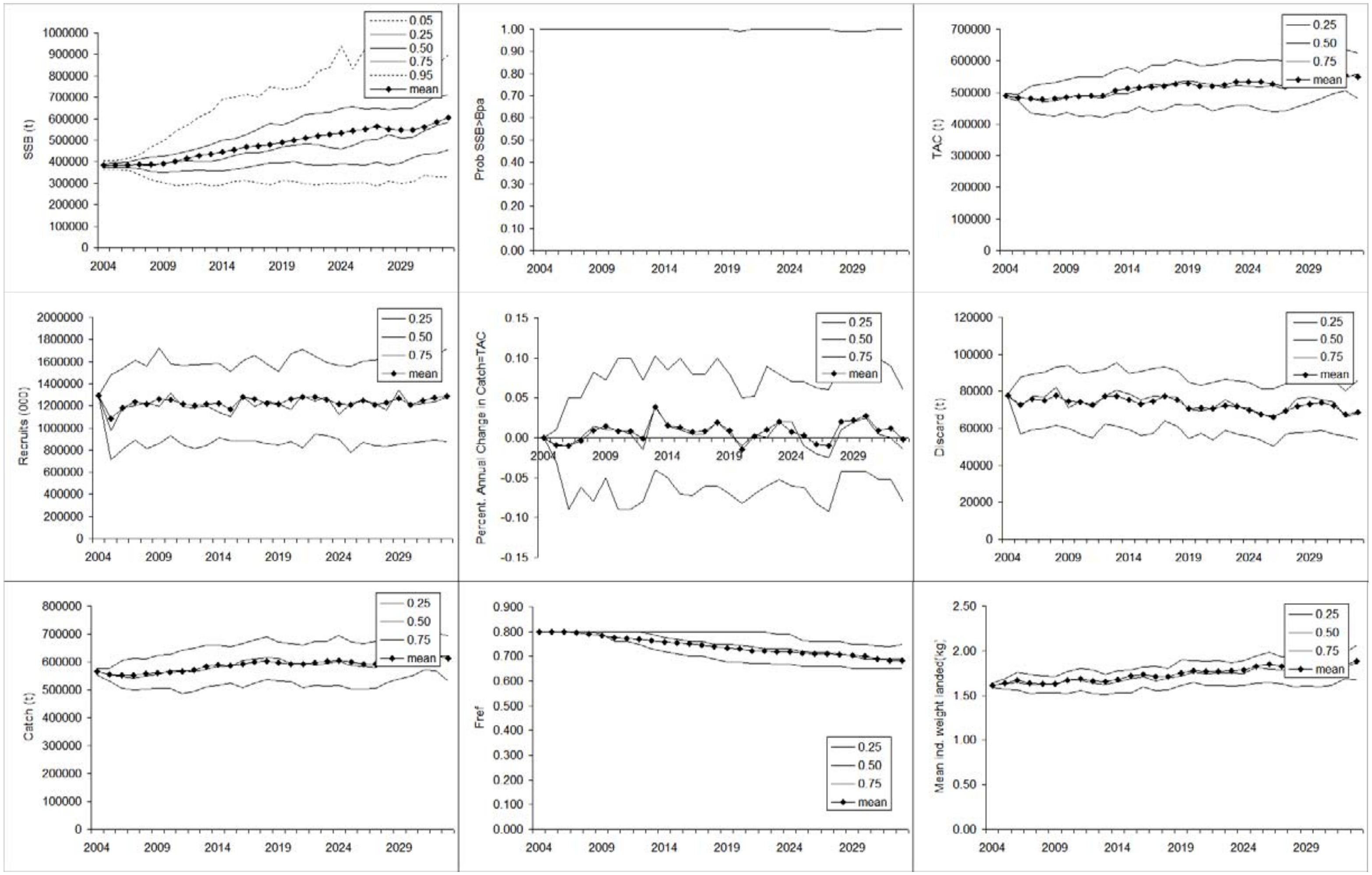
SSB (t)
0.05
0.25
0.50
0.75
0.95
mean
Prob SSB>Bpa
TAC (t)
Recruits (000)
Percent. Annual Change in Catch=TAC
Discard (t)
Catch (t)
Fref
Mean ind. weight landed (kg)
2004
2009
2014
2019
2024
2029

Figure 4.9 Scenario 1: starting stock size at Bmsy, starting fishing mortality below Fpa, Ricker slope at a=6.0. The stock and its exploitation can be considered almost consistent with MSY. Shown are results of the 30 years projections in SSB, probability SSB>Bpa, TAC (landings), recruits, relative annual change in TAC, discards, catch, fishing mortality and mean weight of the fish in the stock.

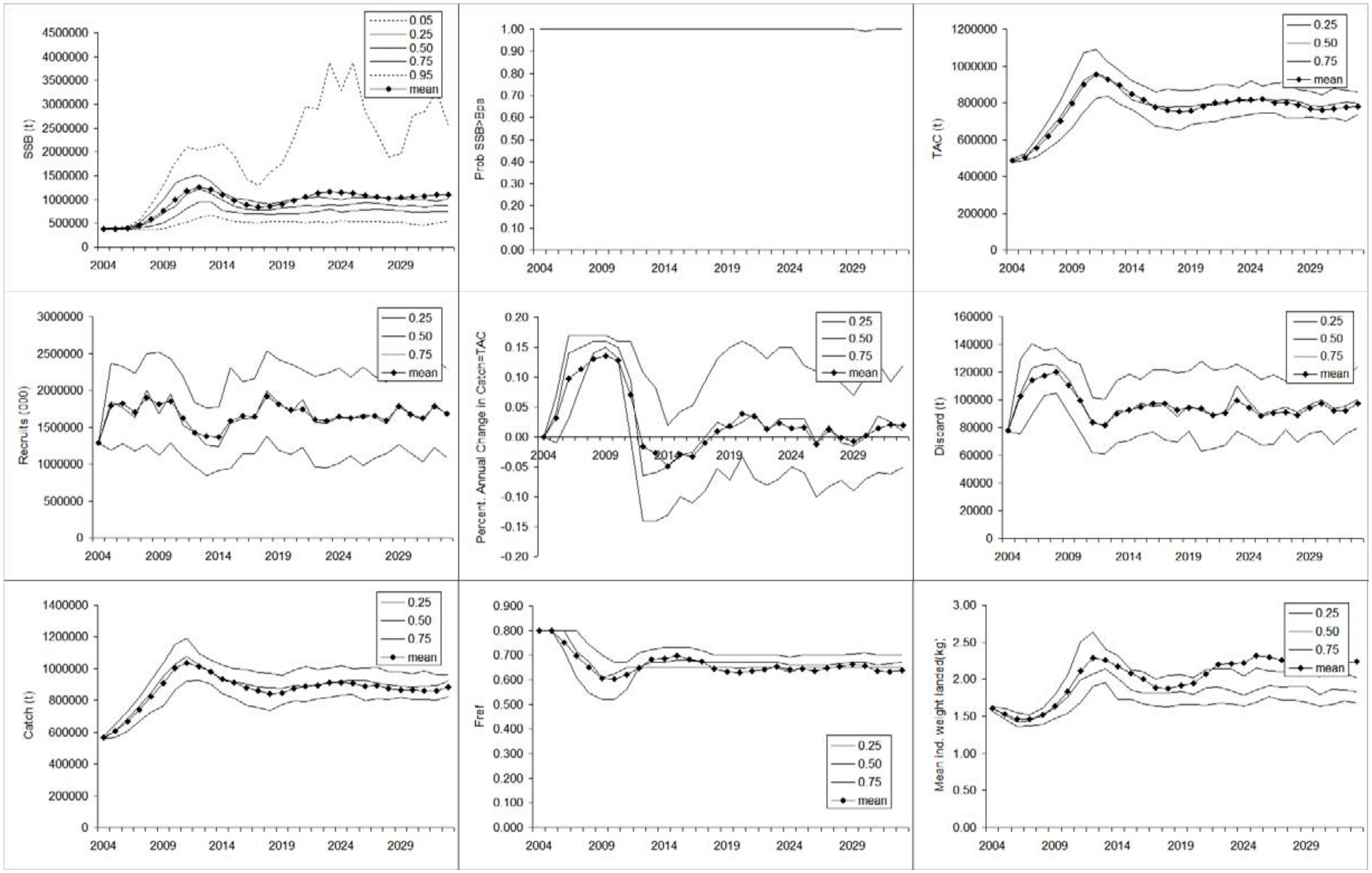

Figure 4.10 Scenario 2: starting stock size at Bmsy, starting fishing mortality below Fpa, Ricker slope at a=9.0. The stock and its exploitation can be considered almost consistent with MSY. However, the higher Ricker slope indicates favourable reproductive potential. Shown are results of the

30 years projections in SSB, probability SSB>Bpa, TAC (landings), recruits, relative annual change in TAC, discards, catch, fishing mortality and mean weight of the fish in the stock.

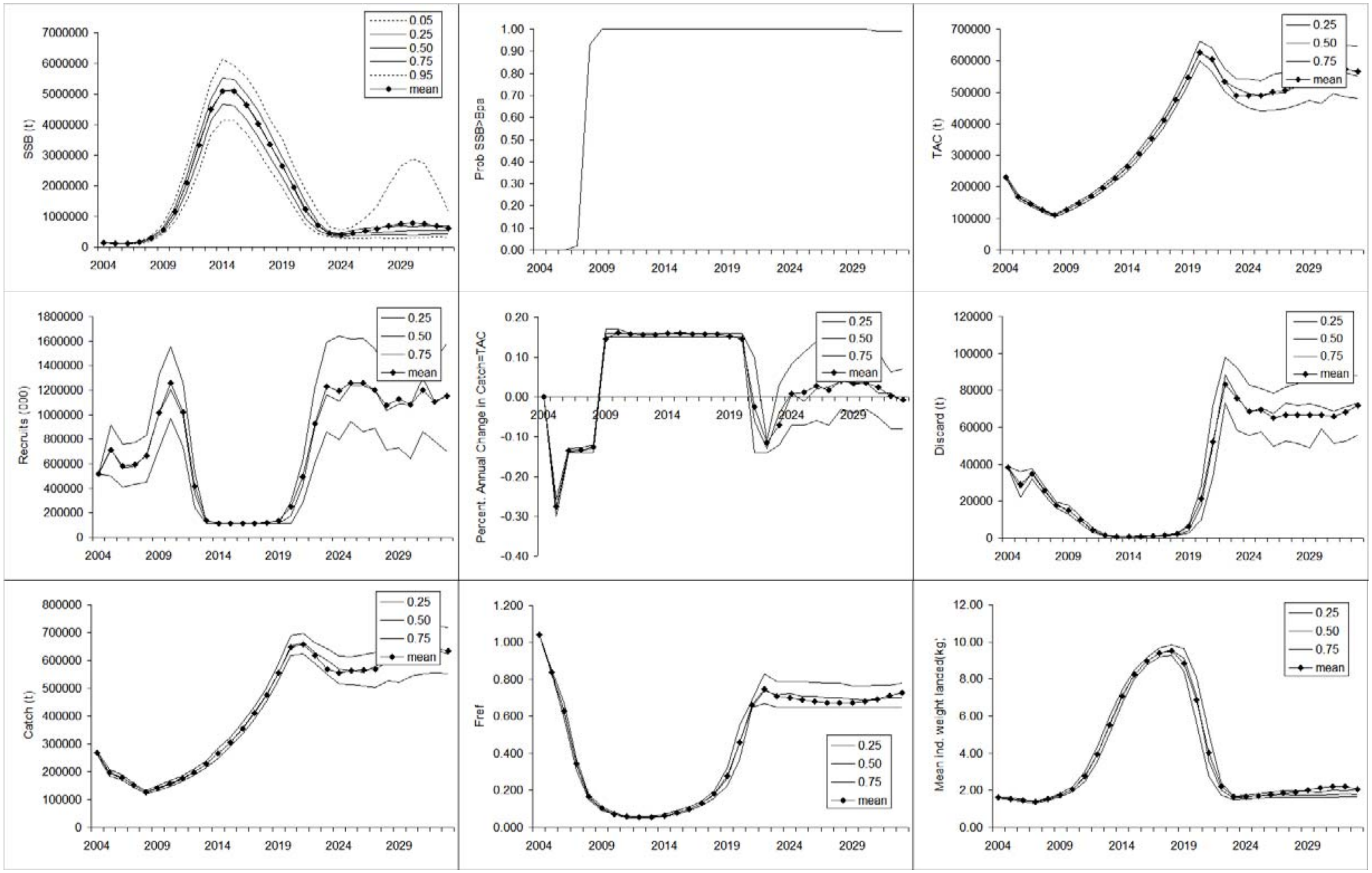

Figure 4.11 Scenario 3: starting stock size below Bpa, starting fishing mortality equals 1.3*Fmsy, Ricker slope at a=6.0. The stock is at risk of reduced reproduction and overfished under normal reproductive potential. Shown are results of the 30 years projections in SSB, probability SSB>Bpa, TAC (landings), recruits, relative annual change in TAC, discards, catch, fishing mortality and mean weight of the fish in the stock.

5. MEETING CONCLUSIONS

5.1. Achievements

There was considerable progress made during the meeting on several issues related to the terms of reference.

The TDRs were described in sufficient detail to allow codeing in computer simulations. This task, while seemingly trivial, required several hours of discussion and debate to ensure a common understanding of terminology and intent. It also became evident, that the three rules could be combined, and with an annual evaluation of population status, the combined rule could be applied for long term projections.

Starting datasets were generated to reflect the intent of the three TDRs. The agreed approach was to select three species with differing life histories to provide contrast in the simulation testing. In addition, it was decided to use two different stock/recruitment formulations for each species reflecting different levels of recruitment compensation (steepness). This is one area that deserves additional attention, however. The limit-cycle behaviour and extremely variable trends in population SSB of the forward projections noted in the SMS and Visual Basic trials indicates that the selections made by the group may not be indicative of realistic biological populations. The enormous cycles of SSB noted in section 4.4 were well beyond the expected range of variation of an exploited marine fish population, and this is likely to be an artefact of the assumed biological dynamics not being realistic.

By the end of the meeting, computer code was written to begin evaluation of the TDRs in three different environments. Having at least three applications was considered an advantage since it provides a basis for comparative algorithm testing. However, it was not possible to fully test each application during the meeting.

5.2. Why the TORs were not fully addressed

Overall, the group was unable to fully address the terms of reference before further analyses have been conducted and a comprehensive test of the model has been completed. The results of some simulations showed model behaviour that could not be fully explained and it was agreed that further work should be undertaken to explore the model dynamics and diagnostics before the presentation of any definitive results.

It was generally agreed that there was insufficient preliminary work done before the meeting. There were many reasons for this including a relatively short notice for the meeting, different interpretations of the TOR, and an underestimation initially of the amount of time needed to do the work. It was agreed that the simulation work required to evaluate the TDRs was complex and required a considerable amount of development and adaptation to the specific questions asked. It was also noted that it took a considerable amount of time at the meeting to describe the TDRs with the amount of detail required for programming. Then, these rules had to be implemented in computer code. However, the progress made at this meeting will be very useful for any future work on this issue.

If the meeting had been scheduled for a longer period of time, more progress would have been made. However, it is also quite difficult to carry out detailed programming and analysis in a working group environment. There would have been no guarantee that the TOR could have been completely addressed if the meeting had been longer.

5.3. Intersessional Work

The translation of the request for policy advice into the basic research question being asked needs a clear and disciplined approach. Once this is clear then the best experimental approach to answer the questions can be identified and the work can proceed. Ideally, this will entail focusing on the predictions of how the fished systems will respond to the TDRs rather than concentrating on describing the behaviour of the simulations. To ensure clear communication it will be necessary to provide a complete description of the simulation procedures and the model equations using some standard notation. In particular, it will be necessary to specify explicitly how recruitment in years y-1 and y is estimated for the forward projections.

Decisions are required on a number of aspects related to the simulation modelling:

- How best to ensure accurate and bug-free codeing? It may be sensible to generate a known test data set that will be useable across programming environments, and be used for cross-validation.
- During the meeting it was not decided to what extend variability in biological parameters such as weight at age, selectivity at age, maturity, etc. should be included in the simulations. This needs to be determined and stated explicitly.
- Also during the meeting, no implementation uncertainty was included in the testing of the TDRs. A decision is required on whether to include this, for example, how should unreported catch and discards be considered?
- There is presently an intrinsic two year time lag between data becoming available (up to year y-2) and setting the TAC (in year y). The influence of this time lag should be explored to determine its influence on the behaviour of the TDRs.
- The different programming environments include simulation strategies that include a formal assessment (such as XSA in the FLR routines) and others that simply simulate the stock assessment process by sampling from the true population (such as the Visual Basic implementation). These can be used to determine how important it is to include an explicit stock assessment model. This is related to whether or not the F and SSB reference points (F_{MSY}, F_{pa}, and B_{pa}) are estimated from simulated data in an assessment or are taken as known.

- Finally, the stock-recruitment functional forms need biological reality. If a Ricker is used, the unfished equilibrium SSB should be relatively close to the biomass giving maximum recruitment. In the codoid example, the unfished equilibrium was more than three times the biomass giving maximum recruitment and this caused huge oscillations in behaviour, something never seen and unexpected. Introducing process error into the stock-recruitment function is also a problem. Lognormal errors is assumed but this could be added as a Monte Carlo process, in which case autocorrelation could also be added. Alternatively, observed residuals could be resampled, although with only short time series of data this may not be sufficiently variable.

5.4. Next Meeting

It was agreed that it would be feasible to hold another meeting in September 10-14, 2007 in order to complete this request. It was also agreed that this will require a considerable amount on intersessional work and communications. The FLR Wiki will be used to archive commonly used code for this work (http://flr-project.org/doku.php?id=appl:stecf_hcr).

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7. MATHEMATICAL NOTATION

α	Density independent parameter in Ricker stock-recruit equation
β	Density dependence parameter in Ricker stock-recruit equation
ε	Error term
ρ	Ratio of applied recruitment to fitted recruitment value
σ	Standard deviation
φ_0	Spawning biomass per recruit from an unfished stock
a	Age
B_{pa}	Spawning Stock Biomass threshold above which stock is considered to be "within safe biological limits". Bpa = SSB corresponding to a yield = $0.5*Y_{MSY}$
B_{MSY}	Spawning Stock Biomass at maximum sustainable yield
B_0	Virgin Biomass. Spawning stock biomass of an unfished stock
C	Catch (Catch ≡ Yield)
exp	Exponential
F	Fishing mortality
F_{MSY}	F giving maximum sustainable yield
F_{mult}	$F_{mult} = F_{target}/F_{SQ}$
F_{pa}	F corresponding to a yield = $0.5*Y_{MSY}$
F_{SQ}	F status quo i.e. the mean F calculated for the terminal year of the assessment.
F_{target}	F in TAC year required by the Harvest Control Rule (HCR)
ln	Natural logarithm
m_a	Proportion mature at age *a*
M_a	Natural mortality at age *a*
$N_{a,y}$	Number of fish at age *a* in year *y*

R	Recruitment
$\hat{R}$	Fitted recruitment value
s_a	Selectivity at age *a*
S	Steepness parameter in Ricker stock-recruit equation
W_a	Mean weight at age *a*
y	Year (year y always refers to TAC year; y-2 the terminal year & y-1 the intermediate year)
Y	Yield (Yield ≡ Catch)
Y_{MSY}	Maximum sustainable yield
Z	Total mortality

8. LIST OF ACRONYMS

ADMB	Automatic Differentiation Model Builder (modelling framework)
B_{MSY}	The spawning stock biomass which generates the MSY if F_{MSY} is applied.
B_{PA}	The spawning stock biomass considered to be the limit below which the stock should not go;the precautionary approach limit.
CEFAS	Centre for Environmental Fisheries and Aquaculture Science
F_{MSY}	Fishing mortality which generates the MSY if the spawning stock is at SSB_{MSY}
F_{PA}	Fishing Mortality Precautionary Approach level.
F_{SQ}	Fishing mortality that maintains the status quo
FLR	Fisheries Libraries in R (modelling framework)

FLXSA	Fisheries Library implementation of Extended Survivor Analysis
FLBRP	Fisheries Library Biological Reference Points
FLCore	Fisheries Library core routines and objects
FLAssess	Fisheries Library Assessment Methods
FLEDA	Fisheries Library Exploratory Data Analysis
FLSTF	Fisheries Library Short Term Forecast
FRS	Fisheries Research Services
HCR	Harvest Control Rule (sometime known as Decision Rule)
ICES	International Committee for the Exploration of the Sea
IPIMAR	Instituto de Investigacao das Pescas do Mar
LRP	Limit Reference Point – the level of a performance measure below which represents an undesirable state for the stock.
MSY	Maximum Sustainable Yield
OM	Operating Model – represents an assumed reality against which to compare the performance of a given management strategy/Harvest Control Rule
PM	Performance Measure – statistics such as stock biomass or fishing mortality rate, which are used in conjunction with Limit and Target Reference Points to characterize the status of a stock.
SR	Stock recruitment – relationship between spawning stock size and subsequent recruitment levels.
SSB_{MSY}	Spawning Stock Biomass which generates the MSY when fished at F_{MSY}.
SSB_y	Spawning Stock Biomass in Year y
STECF	Scientific, Technical and Economic Committee for Fisheries
TAC	Total Allowable Catch
TDR	TAC Decision rule, sometimes referred to as a harvest control rule. In the context of this report, TDR adopts the terminology of COM(2006)
ToR	Terms of Reference
TRP	Target Reference Point

9. EXPERT DECLARATIONS

Declarations of invited experts are published on the STECF web site on https://stecf.jrc.ec.europa.eu/home together with the final report.

European Commission

EUR 23656 EN **– Joint Research Centre – Institute for the Protection and Security of the Citizen**
Title: Scientific, Technical and Economic Committee for Fisheries. Report of the SGMOS-07-01 Working group on the Evaluation of "Policy statement harvest rules".
Author(s): Sinclair, A., Haddon, M., Marchiels, M., Azevedo, M., Garcia, D., de Cardenas, E., Jardim, E., Holmes, S., Scott, R., Mosqueira, I., Vinther, M., Raetz, H. & Kuikka, S.

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Abstract

SGMOS-07-01 was held on 12 – 16 March 2007 in Lisbon (Portugal). The meeting was convened to focus on the examination of the TAC-setting rules in paragraphs 4.1, 4.2 and 4.3 of the Commission's Communication COM (2006) 499 final (Fishing Opportunities for 2007. Policy Statement from the European Commission), and to advise on the likely long-term (ca. 10-year) consequences, and associated risks for the stocks and the fisheries, in terms of a) the future development of spawning biomass, and associated risks of transgressing biological reference points, and b) the future development of yield, and associated risks. STECF reviewed the report during its plenary meeting in April 2007.

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